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Sandia Corporation

BIBLIOGRAPHY

RADIATION EFFECTS

by

Radiation Effects Division 1626

DEPARTMENT OF DEFENSE
PLASTICS TECHNICAL EVALUATION CENTER
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December 1959

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ACKNOWLEDGMENT*

The Radiation Effects Division 1626 wishes to acknowledge the combined efforts of the Radiation Effects Section 1626-1 in making the Radiation Effects Program File operational and, consequently, the publication of this bibliography. However, special recognition must go to S. E. Harrison, 1626-1, and Evelyn L. Amos, 3126-6, for compiling and editing these abstracts for publication.

*PLEASE NOTE

Due to recent organizational changes at Sandia Corporation, all inquiries pertaining to this bibliography should be directed to The Radiation Effects Studies and Measurements Section 1632-1, attention: Kent C. Humpherys.

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RADIATION EFFECTS

INTRODUCTION

Sandia Corporation's Radiation Effects organization has just completed a search of the literature on radiation effects, dosimetry, nuclear test facilities, and other related areas. This search was made as part of the preparation for an expanded radiation effects program Sandia will conduct next year upon completion of its engineering test reactor and pulse reactor. It was thought that the results of this search would be of general value to other organizations and, therefore, the attached unclassified bibliography was prepared. Since Sandia's main concern was background knowledge prior to going into an expanded program, it is not intended that any future editions or revisions of this bibliography will be made.

In the attached bibliography, abstracts are presented in nine categories. These are: dosimetry, health physics, and associated topics; electronic materials, components and systems; metals, alloys and ceramics; nuclear facilities and associated topics; organic chemicals, including fuels, lubricants, and other petroleum products; polymeric materials, including elastomers, plastics, and adhesives; propellants, explosives, and associated topics; shielding; and a miscellaneous section. This document supersedes Sandia Corporation documents SC-4046A(M) and SC-4046B(M).

DOSIMETRY, HEALTH PHYSICS, AND ASSOCIATED TOPICS

DOSIMETRY, HEALTH PHYSICS, AND ASSOCIATED TOPICS

A/Conf. 15/P/761

Schuler R H
ABSOLUTE DOSIMETRY OF IRRADIATIONS WITH CHARGED PARTICLES,
Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 9 pp. (27 refs).

Much of the thinking of radiation chemists today is based on the interpretation of relatively small effects which accompany changes in controllable variables, a very high degree of accuracy is required for many of the experimental measurements. Methods are available for making these measurements under certain idealized conditions. It is the purpose of this presentation to summarize some of the work which has been done to make this possible.

A/Conf. 15/P/1859

Schulman J H
SOLID STATE DOSIMETERS FOR RADIATION MEASUREMENTS,
Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, US Naval Research Laboratory, June (1958), 16 pp. (26 refs).

The past decade has seen a revival of interest in the application of radiation-induced changes of optical properties of solids to the problems of dosimetry. A number of practical dosimetric systems have already evolved from these studies, and still others show a high degree of promise. There is little question that extension of these researches will provide more new and useful devices for low-level and casualty personnel dosimetry, for in vivo dosimetry, and for the measurement of massive doses involved in radiation synthesis, food and drug sterilization, and radiation effects studies.

Specific topics discussed in this report are general theory of operation, dosimeters using coloration effects, radiophotoluminescent dosimeters, luminescence, degradation dosimeters, thermoluminescent dosimeters, and stimulated luminescence dosimeters.

AE-0057-2

Ardashnihov S W and Chetverikov W S
ON THE PROBLEM OF THE DEFINITION OF ROENTGEN IN THE RECOMMENDATION OF THE INTERNATIONAL COMMISSION FOR RADIOLOGICAL UNITS,
Commission for Radiological Units, Atomnaya Energiya, Vol. 3, pp. 238-244 (1957).

The definition of roentgen (r), which was worked out at Stockholm in 1928 and at Chicago in 1937, was examined again in 1953, and a new definition was decided upon. This new definition still has the disadvantage that one roentgen is measured by the "amount of x or gamma radiation." This "amount" is open to various interpretations.

In order to eliminate any ambiguity, it was suggested that a new international definition which takes the following into account should be decided upon: (1) What is being measured by a roentgen: the ionizing effect of radiation the ionizing amount, or the amount of energy? (2) If the amount of energy is to be measured, then what energy is meant; incident energy, or the energy that must be used for corpuscular emission, or the energy that is absorbed in the course of ionization and excitation? (3) Is the absolute amount measured or is it referred to the mass, the volume, or the surface? and (4) If reference is made to mass of a volume in which the corpuscular emission is caused, or the ionized volume in which ionization or excitation took place?

AECD-3169

Campbell E C, Wyly L D and Howell E I
MEASUREMENTS ON THE ORSORT URANIUM-GRAPHITE EXPONENTIAL PILE,
Oak Ridge School of Reactor Technology, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Contract No. W-7405-Eng-26, October 30, 1950, 28 pp. (11 refs).

The purpose of this report is to describe the ORSORT uranium-graphite exponential pile and to present information obtained from measurements made on the neutron flux distribution in the pile.

AECD-3716 CF-53-5-139

Trice J B, et al.
TWO NEUTRON ENERGY MEASUREMENTS IN THE BULK SHIELDING FACILITY USING RADIOACTIVANTS,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, Contract No. W-7405-Eng-26, October 29, 1953, 28 pp.

This report discusses two neutron energy measurements made in the Bulk Shielding Facility.

First Test: Experimental Measurements in the Bulk Shielding Facility with General Species of Radioactivants.

A series of measurements were made in the Bulk Shielding Facility in order to compare results from nuclear threshold measurements. At present it can be stated that both measurements, made adjacent to the reactor, show the general shape of a fission spectrum over the energy region where comparison is possible.

Second Test: Traverse Measurement of High Energy Neutrons Through a Bulk Shielding Facility Lattice Element.

A project to measure the $O^{16}(N, P)N^{16}$ and $O^{17}(N, P)N^{17}$ cross sections for fission neutrons was initiated because of the importance of these two reactions to the submarine shielding program. Since, in a circulating water or steam reactor system, the water passes through both a high intensity neutron field and a region where personnel may be required to work, most of the biologically dangerous radiation must result from the induced activities in the circulating water.

The experiment was simulated in the Bulk Shielding Reactor by circulating water upward through a special fuel element and through a pipe leading to a neutron counter for one measurement and a gamma counter for the other measurement.

AECD-3720 CF-53-5-105

Cochran Robert G and Henry Keith M
FAST NEUTRON SPECTRA OF THE BSF REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, Contract No. W-7405-Eng-26,
May 29, 1953, 11 pp.

The proton recoil fast neutron spectrometer has been used to measure the spectra at the north face of the Bulk Shielding Facility Reactor and at several positions in the water nearby. In reporting the data, each spectrum is identified by the distance between the end of the collimator and the nearest fuel (i.e., measurements were made against the fuel and at varying distances from the fuel). In all measurements, the collimator was pointed directly toward the center of the reactor.

It has been assumed for this experiment that a collimator with a large ratio of length to diameter does not distort the neutron spectrum.

AECD-3721 CF-53-12-51

Cochran R G and Henry K M
FAST NEUTRON SPECTRUM OF THE LITR,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, Contract No. W-7405-Eng-26,
December 31, 1953, 7 pp.

The Bulk Shielding Facility fast-neutron spectrometer has been used to measure the neutron spectrum of the Low Intensity Training Reactor (LITR).

The HB-2 hold, which penetrates the reactor shield to the active core, was chosen for the measurement. Since a high flux of neutrons and gamma rays would stream out of the collimator hole during reactor operation, an external shield as shown in Figure 2 was needed for personnel protection. The shield surrounded the spectrometer, intercepting both direct and scattered radiation, and was found to be more than adequate for reducing radiations below laboratory tolerance in the east experimental room of the LITR building.

The resulting spectrum is plotted in Figure 3. This data shows the outward-directed fast-neutron current at the face of the reactor since corrections have been made for the 12 ft collimator.

AECD-3986

Uecker D F
TRAVELING PROBE FOR ZPR-II,
Remote Control Engineering Division, Argonne National Laboratory, Lemont, Illinois,
Contract No. W-31-109-Eng-38, August (1953), 21 pp.

The ZPR-II facility made provisions for probing along both horizontal and vertical axes. Separate but functionally similar probes were used for each axis: an ion chamber at one end of a length of rigid aluminum tubing was connected to its galvanometer tube and amplifier at the other end by a coaxial cable passing through the bore. This entire assembly was inserted to the desired depth in air-filled sleeves passing through the fuel lattice. Six fixed sleeves were provided in the horizontal direction, while two vertical sleeves were capable of installation in any of a multiplicity of locations.

For the Savannah River facility, it was requested that the probe not be limited to discrete axes but be capable of travel anywhere in a plane between rows of fuel.

Briefly, this equipment consists of a trolley-mounted chamber which can be moved horizontally along a track, or vertically, as the entire track is raised or lowered. A third power unit keeps a proper length of electrical cable paid out, the entire process being controlled and recorded at a remote location.

This report consists of a detailed description of the traveling probe and associated electrical and mechanical mechanisms.

An appendix is included which discusses neutron probe construction.

AECU-1020 KAPL-P-484

Whittlesay Eunice and Givens Eloise
RADIATION PROTECTION OF PERSONNEL AND RADIOCHEMICAL LABORATORIES, THEIR DESIGN AND OPERATION,
A Bibliography, General Electric Company, Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, July (1950), 23 pp. (188 refs).

This bibliography was compiled to fulfill the request for sources of information on the special problems in the field of radiochemistry-radiation protection of personnel and radiochemical laboratories, their design and operation. The material is arranged by general background, radiation protection of personnel, and radiochemical laboratories, their design and operation.

AECU-1321

Hamill William H, et al.
HOT RADICAL REACTIONS,
A Review of Principles and a Critical Discussion of Experiments, University of Notre Dame, Notre Dame, Indiana, Contract No. AT(11-1)-38, March 1, 1951, 49 pp. (44 refs).

This report is a copy from rough draft of the basic principles of hot radical reactions. It has a thorough discussion of experiments on hot radical reactions involving basically the holides.

AECU-1269 AT1-117-032

THE INDUSTRIAL UTILIZATION OF FISSION PRODUCTS; (GROSS, MIXED AND SEPARATED); A PROSPECTUS FOR MANAGEMENT,
Stanford Research Institution, Stanford, California, March (1951), 45 pp. (24 refs).

The purpose of this prospectus is to provide preliminary, advance information to industry concerning the possible availability of large quantities of fission products. The study is being sponsored as a service to industry by the USAEC, under contract to the Division of Reactor Development.

The uses described are intended only as a guide to show how the properties of these materials might be used to advantage in industry. Little actual experience has been gained using fission products in industry and, therefore, suggested potential uses must

be speculative in nature, based on experience gained from the use of pure isotopes and on technical calculations using available data.

In general this report covers description of fission products, possible industrial uses for fission products, availability and cost of fission products, general considerations in the use of fission products, and a glossary of terms.

AECU-1344

Burton Milton
AN INTRODUCTION TO RADIATION CHEMISTRY,
Work done at University of Notre Dame, Notre Dame, Indiana, Contract No. AT(11-1)-38,
Journal of Chemical Education, August (1951), 16 pp. (69 refs).

Radiation chemistry is the chemistry of the effects of high-energy particles and radiations, including both radioactive emanations and the energetic products of high-voltage machines and nuclear reactors.

The early days of radiation chemistry are discussed. The photochemical analogue is discussed with respect to the Grotthus-Draper law and the Stark-Einstein law. Also included is a section on radiation particles, sources, employment, and primary effects, a section of theory and illustrations, and a section on research possibilities.

AECU-1619

BASIC RADIATION DAMAGE STUDIES WITH CHARGED PARTICLES,
Final Technical Report, July 1, 1950 - June 30, 1951, Purdue Research Foundation,
Lafayette, Indiana, Contract No. AT(11-1)-117, 22 pp.

The work under this contract was concerned with effects of irradiation with natural radioactive material (polonium) on thin films, with the investigation of structure changes due to irradiation both with natural alpha particles of polonium as well as deuterons from the cyclotron and neutrons from the Oak Ridge reactor, the investigation of the thermal properties of irradiated materials, and finally the development of pulse heating equipment to study the healing process in irradiated specimens.

Preirradiation work has been performed on the specific heat of silicon and germanium.

The thin film experiments were undertaken primarily to be able to use alpha particles of polonium and to observe the Hall-effect as a function of irradiation. A method was developed to determine the structure of material before and after irradiation with nuclear particles in the cyclotron or with neutrons. Radiation damage to high polymers is also discussed.

As part of the program on the bombardment of germanium single crystals, various crystals were tested before irradiation by taking back reflection Laue patterns. The electron diffraction studies were accomplished using a single crystal of N-type germanium. Etched and reflection electron diffraction pictures were taken.

AECU-3144

Clark Herbert M and Neil Donald E
A TABLE OF RADIONUCLIDES ARRANGED ACCORDING TO HALF-LIFE,
Rennselaer Polytechnic Institute, Troy, New York, December (1955), 223 pp. (5 refs).

This table is a revision of US Atomic Energy Commission Report, MonC-400, "A Table of Radioactive Isotopes Arranged According to Half Lives." MonC-400 was issued in 1947 as an aid in radioactivation analysis and in the identification of radionuclides produced in activated materials in general. The table was based on unclassified information published up to July 1, 1947. The revised table includes information tabulated in the 1953 "Table of Isotopes" by Hollander, Perlman, and Seaborg, and in Nuclear Science Abstracts through the 1954 Annual Cumulated List of "New Nuclear Data."

Alpha emitters, excluded as a class from MonC-400, are included in the new table. In addition, there are several minor changes in format and in the type of information given. As for the first edition, the arrangement of data makes the table useful also in connection with the selection of nuclides according to type and energy of radiation. By scanning the appropriate radiation column, one can find rather rapidly those nuclides having approximately the desired energy.

AECU-3446

Zimmer Lawrence T
DOSIMETRY OF KILOCURIE CO^{60} SOURCES,
Argonne Cancer Research Hospital, University of Chicago, Chicago, Illinois, October (1956), 20 pp. (16 refs).

In an effort to determine the γ-ray intensity from several Co^{60} sources, some primary and secondary dosimeters were constructed. Methods of calorimetry, ferrous sulphate oxidation, ionization chambers, and photographic film were studied and radiation intensity evaluated. Results from the absolute determinations were compared with those from a Victoreen condenser-type r-meter calibrated by the National Bureau of Standards for Co^{60}, and the ionic yield of ferrous sulphate measured.

The sources used were hollow cylinders of Co^{60} supplied by Brookhaven National Laboratory in an apparatus described by Baarli and Shaggs and small solid rods of Co^{60} from Argonne National Laboratory in a medical teletherapy unit described by Lanzel, et al. All results are given for a standard position in the BNL sources and for a standard distance from the ANL sources.

AECU-3565

Carroll J G
MONITORING THE MTR CANAL GAMMA SOURCE - A TREATMENT OF RELIABILITY,
California Research Corporation, Richmond, California, Contract No. AT(11-1)-174, August 31, 1957, 15 pp. (6 refs).

Spent fuel elements from nuclear reactors are used extensively as gamma radiation sources. Such a source has been in operation since 1952 at the National Reactor Testing Station in Idaho. Fuel from the Materials Testing Reactor is utilized. These MTR fuel elements are arranged in an angle-iron grid work which is placed under 18 feet of

water in the MTR canal. California Research has been exposing samples in this source since 1953. This discussion pertains to exposures made between October 1955 and April 1956.

Radiation flux gradients exist in both the horizontal and vertical directions in the submerged location. Such gradients pose measuring problems in obtaining reliable values for dosages received by samples. This report pertains to this treatment of these problems.

AEC-WASH-1

AEC ISSUES EFFECTIVE REGULATION ON STANDARDS FOR PROTECTION AGAINST RADIATION,
US Atomic Energy Commission, Washington 25, D.C., January 25, 1957, 33 pp.

This is a regulation, effective February 28, 1957, establishing standards for the protection of atomic energy workers and the public against radiation hazards arising from activities licensed by the Commission. Principal changes since the regulation was first published (July 1955) as a proposed rule are listed.

The following are discussed: permissible doses, levels, and concentrations; precautionary procedures; waste disposal; records, reports, and notification; exceptions and additional requirements; enforcement; and general provisions.

AERE-C/R-1575 (Suppl 1)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, March (1957), 209 pp.

This bibliography is the 1957 Supplement to the documents AERE-C/R-1575, Parts 1 to 6. For convenience, separate supplements are not being published to each of the 6 parts of the AERE-C/R-1575; one supplement per year will be issued to cover all these parts. These supplements will, however, be sectionalized to correspond with the separate parts of AERE-C/R-1575, thus:

Section 1. Theory, Interpretations, Water and Aqueous Inorganic Systems
Section 2. Organic Compounds (including polymerization reactions)
Section 3. Gaseous Systems (excluding organic compounds)
Section 4. Solid Systems (excluding organic compounds)
Section 5. Biochemistry and Radiobiology (excluding animal studies)
Section 6. Miscellaneous (including colloids, corrosion, industrial applications of radiation, irradiation equipment, general reviews, etc.).

In the individual sections, report abstracts are given first, followed by annotated "open literature" references. The report references are arranged alphabetically and serially by report reference number, and the "open literature" references by "first named author." Author and subject indexes are provided. The opportunity is being taken to include recently declassified American reports and a few older literature references not included in the earlier parent review.

AERE-C/R-1575 (2)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE (ORGANIC COMPOUNDS),
Atomic Energy Research Establishment, Harwell, Berkshire, England, March (1956), 225 pp.

Section 1 consists of a collection of abstracts relating to American, Canadian and British unclassified and declassified Atomic Energy Project reports, noted up to March 1956. The abstracts are arranged alphabetically and serially by report reference number.

Section 2 consists of published literature references (1900-March 1956) arranged alphabetically by "first named author."

Author and subject indexes are provided.

AERE-C/R-1575 (Suppl 2)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, (1958), 326 pp.

This bibliography is the 1958 Supplement to the documents AERE-C/R-1575, Parts 1 to 6. The supplement is sectionalized to correspond with the separate parts of AERE-C/R-1575, thus:

Section 1. Theory, Interpretations, Water and Aqueous Inorganic Systems
Section 2. Organic Compounds (including polymerization reactions)
Section 3. Gaseous Systems (excluding organic compounds)
Section 4. Solid Systems (excluding organic compounds)
Section 5. Biochemistry and Radiobiology (excluding animal studies, including irradiation of foodstuffs, etc.)
Section 6. Miscellaneous (including colloids, corrosion, industrial applications of radiation, irradiation equipment, general reviews and reports, etc.).

In the individual sections, project report abstracts are given first, followed by annotated "open literature" references. The report references are arranged alphabetically and serially by report reference number, and the "open literature" references by "first named author." Author and subject indexes are provided. The opportunity is being taken to include recently declassified American and British reports, and a few older literature references not included in earlier issues.

The scope of Section 5 has been enlarged by inclusion of references to the irradiation of foodstuffs, bacteria, insects, etc., and Section 6 has been enlarged by inclusion of fuller references on the industrial utilization of radiation--a separate document on the latter subject will not be issued, although such was mentioned in earlier issues.

Use has been made of the USAEC Abstract Card service and Nuclear Science Abstracts in compiling this survey, and very grateful thanks are expressed to the USAEC for permission given. Grateful thanks are also due to Chemical Abstracts. Abstracts Journal references are given where available (CA = Chemical Abstracts, NSA = Nuclear Science Abstracts).

AERE-C/R-1575 (3)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE (GASEOUS SYSTEMS),
Atomic Energy Research Establishment, Harwell, Berkshire, England, March (1956), 59 pp.

Section 1 consists of a collection of abstracts relating to American, Canadian and British unclassified and declassified Atomic Energy Project reports, noted up to March 1956. The abstracts are arranged alphabetically and serially by report reference number.

Section 2 consists of published literature references (1900-March 1956) arranged alphabetically by "first named author."

Author and subject indexes are provided.

AERE-C/R-1575 (4)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE (SOLID SYSTEMS),
Atomic Energy Research Establishment, Harwell, Berkshire, England, May (1956), 135 pp.

Section 1 consists of a collection of abstracts relating to American, Canadian and British unclassified and declassified Atomic Energy Project reports, noted up to May, 1956. The abstracts are arranged alphabetically and serially by report reference number.

Section 2 consists of published literature references (1900-May 1956) arranged alphabetically by "first named author."

Author and subject indexes are provided.

AERE-C/R-1575 (5)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE (BIOCHEMISTRY AND RADIOBIOLOGY),
Atomic Energy Establishment, Harwell, Berkshire, England, May (1956), 91 pp.

Section 1 consists of a collection of abstracts relating to American, Canadian and British unclassified and declassified Atomic Energy Project reports, noted up to May 1956. The abstracts are arranged alphabetically and serially by report reference number.

Section 2 consists of published literature references (1900-May 1956) arranged alphabetically by "first named author."

Author and subject indexes are provided.

AERE-C/R-1575 (6)

Clarke R W
SELECTED ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORT LITERATURE IN THE FIELD OF RADIATION CHEMISTRY AND BIBLIOGRAPHY OF THE PUBLISHED LITERATURE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, May (1956), 54 pp.

This part of AERE-C/R-1575 is divided into sections as follows:

Section 1. Industrial Applications of Radiation
Section 2. Colloidal Systems
Section 3. Corrosion Effects
Section 4. Irradiation Equipment
Section 5. Miscellaneous Systems
Section 6. Miscellaneous Review Papers

It contains material for which no "home" was found in Parts 1 to 5. In each section, abstracts relating to American, Canadian and British unclassified and declassified Atomic Energy Project reports noted up to May 1956 are given first, and arranged alphabetically and serially by report reference number; these are followed by published literature references arranged alphabetically by "first named author."

Author and subject indexes are provided.

AERE-C/R-1759

White A G
A RAPID DIFFERENTIAL THERMOMETRIC METHOD FOR DETERMINING THE ENERGY OUTPUT OF RADIOACTIVE MATERIALS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, October 5, 1955, 12 pp. (2 refs).

A method is described for obtaining a direct measurement of the rate of change of temperature with time, using a large capacity condenser and a galvanometer to differentiate the potential changes in a thermistor circuit. A description of two calorimeters embodying this principle, with which the energy outputs of radioactive samples may be determined, is given. The theoretical basis of the method is examined and means of estimating correction terms are suggested.

AERE-EL/L-7

Barnes R K
LECTURE ON ERROR AND CORRECTION IN COUNTER WORK, COUNTER-EFFICIENCY, AND SOURCE GEOMETRY,
Atomic Energy Research Establishment, Harwell, Berkshire, England, 10 pp.

This paper discusses statistical distribution losses and other topics relative to error and correction in counter work, counter efficiency, and source geometry.

AERE-E1/L-10

Owen R B
SOME NOTES ON SCINTILLATION COUNTING,
Atomic Energy Research Establishment, Harwell, Berkshire, England, March 16, 1954,
10 pp. (9 refs).

These notes discuss the essentials of a scintillation counting system, multiplier photocells, phosphor materials, and scintillation assay and spectrometer equipment.

AERE-EL/R-2326

Iredale P and Humphreys D L O
THE ANALYSIS OF LOW LEVEL GAMMA-RAY ACTIVITY BY SCINTILLATION SPECTROMETRY,
Atomic Energy Research Establishment, Harwell, Berkshire, England, August (1951),
6 pp. (6 refs).

A 3 x 3 in. sodium iodide crystal and multichannel pulse amplitude analyser have been used to measure the activities of the gamma-ray emitters present in sources of low activity. The samples used to illustrate the application of the method were filter papers containing small amounts of nuclear explosion debris collected at high altitude for radiological investigations. It is shown that it is possible to measure the gamma-ray activity of several isotopes present in one sample when the activity of each is 10^{-11} curies or less.

AERE-HP/R-1905

Cocking S J, Delafield H J and Smith J W
A LOW BACKGROUND COUNTING EQUIPMENT WITH ANTICOINCIDENCE ARRAY,
Atomic Energy Research Establishment, Harwell, Berkshire, England, January (1955),
12 pp. (12 refs).

A complete equipment has been designed for accurate assay of β-active gas of up to 350 cc volume and disintegration rates of 10 to 500 per minute. Large Geiger-Müller counters (volume 730 cc) are described and also the arrangement of an anticoincidence array for reduction of background. The residual background rate obtained (5 counts per minute) is discussed.

AERE-M/M-101

LeClair A D
THE AUTORADIOGRAPHIS DETERMINATION OF SELF-DIFFUSION COEFFICIENTS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, August 29, 1955,
4 pp. (4 refs).

A simple mathematical expression is derived for the calculation of Diffusion Coefficients from data obtained by the autoradiographic method.

AERE-M/M-202

Thompson M W
THE INFLUENCE OF NEUTRON ENERGY SPECTRUM ON THE PRODUCTION OF IRRADIATION DAMAGE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, August (1958), 4 pp.

A comparison of the damage produced by epithermal and fission neutrons demonstrates the influence of neutron energy spectrum on the rate of production of irradiation damage. Heavy elements are shown to be more sensitive to a change in spectrum than light elements.

AERE-MT/N-37

Thewlis J and Derbyshire R T P
NEUTRON RADIOGRAPHY,
Atomic Energy Research Establishment, Harwell, Berkshire, England, July (1956), 18 pp.

The absorption of neutrons by matter is considered and the raison d'être of neutron radiography explained. The production and detection of neutrons are described and details are given of the techniques used for neutron radiography at Harwell. Some examples of neutron radiographs are reproduced and discussed.

AERE-NP/R-2096

Allen W D and Ferguson A T G
THE MEASUREMENT OF FAST NEUTRON FLUX OVER THE NEUTRON ENERGY RANGE 0.030 MEV TO 3.0 MEV,
Atomic Energy Research Establishment, Harwell, Berkshire, England, October 3, 1956, 21 pp. (19 refs).

Measurements of neutron flux in the neutron energy region 0.030 Mev to 3.0 Mev have been made using a proton recoil counter and a Hanson-McKibben-type long counter. Several proton recoil counters filled with different gases at different pressures have given flux measurements self-consistent to 2 per cent. The long counter has been calibrated against photoneutron sources at a number of energies and also against the recoil counter. The variation of its efficiency as determined by the two methods is in satisfactory agreement. The absolute calibration of the long counter with respect to a RdTh, D_2O source whose strength was known to ±2-1/2% agreed with the calibration with respect to the recoil counter of 1%. A similar cross check with an Ra-Be source gave an initial discrepancy of 15%, but this was traced to an error in the source strength and variation with energy in the response of the long counter. These cross checks are satisfactory, and over the major portion of the energy range the standard error is not more than ±3%.

AERE-TM-108

Lomer W
THE DIRECT CONVERSION OF BETA-IRRADIATION ENERGY INTO LOW-VOLTAGE ELECTRICAL ENERGY,
Atomic Energy Research Establishment, Harwell, Berkshire, England, April (1954).

A theory is presented that accounts for observations on the emf produced by a semiconductor junction under irradiation. It is shown that, for high efficiency, a semiconductor with a large energy gap, and with both p and n material as heavily doped as is practicable, should be placed in a very high irradiation density. The most effective conditions under which to use a semiconductor under irradiation as a battery are presented.

AERE-T/R-1008

Mandl M E (Mrs.)
A METHOD OF MEASURING THE AVERAGE ENERGY OF A NEUTRON SPECTRUM IN THE RANGE 0.3 TO 3.0 MEV,
Atomic Energy Research Establishment, Harwell, Berkshire, England, August (1952), 12 pp. (1 ref).

For biological irradiation experiments, it is usually necessary to know the average energy of the neutron flux to calculate the relative biological efficiency factor. This average energy can, of course, be measured very accurately by a photographic plate technique, but this is a very laborious method and this degree of accuracy is not usually necessary.

In this report is described a simple method of estimating the average energy of a spectrum of Mev neutrons with an accuracy of about 20%.

The average energy is deduced from the shape of the induced thermal neutrons spatial distribution in a sphere of paraffin.

Where time and space allow, and where very great accuracy is not necessary, e.g., in animal irradiation experiments with Mev neutrons, this method has considerable advantages with it simplicity. The method has been checked experimentally at energies of 0.6 Mev and 2.9 Mev where it is in good agreement.

AF-SAM-56-15

Sigoloff Sanford C, 1/Lt. (USAF)
A HALOGENATED HYDROCARBON-DYE WATER EQUIVALENT METHOD FOR MEASURING - AND GAMMA RADIATION,
Department of Radiobiology, School of Aviation Medicine, USAF, Randolph AFB, Texas, March (1956), 4 pp. (8 refs).

Chemical dosimetry of ionizing radiation has been an important phase of recent radiation research. Free radicals and molecular products formed by the action of radiation on water enter readily into many chemical reactions. Ferrous ions are oxidized to ferric ions, ceric ions are reduced to cerous ions, proteins are denatured, and enzymes are inactivated when they are irradiated in aqueous solutions.

Water is used as the basic medium for this chemical dosimeter because of the possible correlation between chemical effects and biologic effects.

This paper deals with the preparation and uses of a water equivalent method of dosimetry.

AF-SAM-57-86

Sigoloff Sanford C, 1/Lt. (USAF(MSC))
CHEMICAL SYSTEMS FOR THE MEASUREMENT OF PENETRATING RADIATIONS,
Department of Radiobiology, School of Aviation Medicine, USAF, Randolph AFB, Texas, May (1957), 38 pp.

This report outlines techniques for the production of chlorinated hydrocarbon dosimeter systems that have application in the Aircraft Nuclear Propulsion Program. Some of the systems discussed are the tetrachloroethylene two-phase dosimeter and the single-phase water dosimeter. Included are instructions for evaluation as well as a discussion of the ranges and properties of each system.

AF-SAM-57-90

Cassen, Benedict, Ph. D, et al.
DEVELOPMENT OF A GERMANIUM CRYSTAL DOSIMETER,
School of Aviation Medicine, USAF, Randolph AFB, Texas, May (1957), 8 pp. (2 refs).

The most satisfactory material found for use as a fast neutron dosimeter has been made by purifying and crystallizing 30 ohm-cm germanium three times with three zones of a zone-melt furnace and adding 0.026 mg of indium per kilogram of germanium. Good crystal structure is important and requires a good seed crystal and zone widths between 1 and 1-1/2 inches. Close temperature control appears to be required to make reliable cold-bath resistance measurements with the consequent accuracy of ΔC calculations.

AFSWC-TN-56-2

Dick James L, Major (USAF), Hurdlow William R, 1/Lt. (USAF) and
Hippeli Ellen M, 1/Lt. (USAF)
SAFE LEVELS OF CONTAMINATION FROM FISSION PRODUCTS,
Research Directorate, Air Force Special Weapons Center, Kirtland AFB, New Mexico, April 27, 1956, 26 pp. (18 refs).

The radiation hazard resulting from fission product contamination of aircraft, aircraft parts, and air base facilities can be classified as being an external and/or an internal hazard. The external hazard can be determined using a gamma survey instrument and film badges. However, the internal hazard constitutes a more complex problem, in that the measurements must be interpreted in terms of the age of the mixed fission products to establish the true magnitude of the hazard. As a result of this approach, higher contamination levels than those given in present USAF publications are proposed within the limits of current adopted national standards of radiation tolerance. Air sampling is the recommended method for determining the existence of an internal hazard.

Limits of external and internal radiation levels are recommended for those items of materiel which may be released for general usage. Also recommended are limits for items kept in a controlled area, dosage limits for personnel working in such an area, and limits applicable to emergency situations.

AIF-57-32

Stevens A J, Dr.
RADIOISOTOPE USE EXPERIENCE WITH COMMERCIALLY AVAILABLE INSTRUMENTS,
Budd Company, Philadelphia 32, Pennsylvania. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, New York, October (1957), 9 pp.

The author gives a brief description of Budd Company's facility for handling radioactive materials. He discusses monitoring equipment, customers' instrumentation problems, types of instrumentation needed, geiger counter limitations, calibration problems, dosimeters and film badges, and current survey instrumentation.

AIF-57-33

Morgan Karl Z
MEASUREMENT PROBLEMS OF RADIOISOTOPE USERS,
Oak Ridge National Laboratory, Oak Ridge, Tennessee. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, New York, October (1957), 10 pp.

This paper is of a general nature and discusses the problems of the radioisotope users in the measurement of ionizing radiation and points out that present problems are much simpler than those which faced the directors of the Manhattan Project, the Metallurgical Laboratory, the Clinton Laboratory, and the other early contractors in the field of atomic energy.

Specific topics discussed are general improvement in standards and equipment; pocket meters; film badges; neutron monitoring and survey instruments; X-ray survey meters; value of health physics; and radiation instrument requirements.

AIF-57-105

Morgan B W
INSTRUMENTATION REQUIREMENTS OF RADIOISOTOPE USERS,
Division of Civilian Application, US Atomic Energy Commission. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, New York, October (1957), 12 pp.

This paper is directed primarily toward industrial management and does not deal with the technical aspects of radiation detection and measurement. Specific topics discussed are licensing, radiation standards, evaluation of radioisotope program safety, and types of radiation instruments.

AIF-57-106

Aebersold Paul C
REWARDS AND REQUISITES OF ACCELERATING RADIOISOTOPE UTILIZATION,
Assistant Director, Division of Civilian Application, USAEC. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, New York, October (1957), 7 pp.

This paper discusses the extensive benefits to our national welfare and economy which have resulted due to an accelerated radioisotope program. Specific topics discussed are isotope training, isotope demonstrations, and isotope production.

AIF-57-109

Lowenstein Robert
DOMESTIC LICENSING AND REGULATIONS,
Office of General Counsel, USAEC. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, New York, October (1957) 11 pp.

This paper discusses the changes in AEC's licensing procedures under amendment to the Atomic Energy Act enacted at the last session of Congress, a few problems related to the licensing program, and a number of amendments to AEC regulations issued during the past year.

ANL-5206

McDonell William R
RADIATION CHEMISTRY OF NORMAL AND HEAVY WATER SOLUTIONS - I. RADIATION-INDUCED OXIDATION OF FERROUS SULFATE,
Chemistry Division, Argonne National Laboratory, P.O. Box 299, Lemont, Illinois, Contract No. W-31-109-Eng-38, January 12, 1954, 6 pp. (6 refs).

The Co^{60} gamma-ray-induced oxidation of ferrous sulfate in 0.8 N sulfuric acid-heavy water solutions proceeds with a specific yield, G_{Fe}^{+++}, of 17.5, compared to 15.6 for normal water solutions. Pile irradiation yields show a similar but smaller enhancement of ferric ion yields in heavy water solutions, the difference probably due to greater flux of capture gamma radiation in the normal water than in heavy water solutions.

ANL-5743

Aver J E, Davis D A and Mayfield R M
GLOVES FOR PROTECTIVE ENCLOSURES,
Argonne National Laboratory, P. O. Box 299, Lemont, Illinois, Contract No. W-31-109-Eng-38, May (1957), 22 pp. (4 refs).

A study of the glove problem has been made by the ANL Glove Committee as a necessary prerequisite to any attempt at coordination or standardization. This report consists of a compilation of the findings of the Committee and the resulting compromises which are felt necessary to the resolution of the problems.

Materials, methods of manufacturing and general properties of gloves are described. Glove design has been analyzed and suggestions are made in regard to an acceptable standard. Permeability characteristics of various glove compounds are reviewed and the effect of moisture contamination upon hypothetical systems is tabulated. An electrical test is proposed for the determination of glove soundness.

ANL-5819

Swope Gladys H
DOSIMETRY IN THE ARGONNE HIGH-LEVEL GAMMA-IRRADIATION FACILITY,
Chemical Engineering Division, Argonne National Laboratory, P.O. Box 299, Lemont, Illinois, Contract No. W-31-109-Eng-38, January (1958), 12 pp.

This report discusses chemical dosimetry, utilizing the oxidation of ferrous sulfate, as used to measure radiation intensity of the Argonne National Laboratory's High-Level Gamma Irradiation Facility.

The preparation of ferrous sulfate solution is described. Ferrous dosimetry calculations are presented. Photographs are included showing a polystyrene dosimeter cell holder, an irradiation urn, and irradiation rack.

APEX-134

Moteff John
FISSION PRODUCT DECAY GAMMA ENERGY SPECTRUM,
Aircraft Nuclear Propulsion Project, General Electric Company, Cincinnati, Ohio,
June (1953), 78 pp. (15 refs).

A study has been made to determine the gamma energy spectrum of the thermal-fission products of U^{235} at various times after shutdown of a reactor. The results yield the energy spectrum for 1000 hours of reactor operation and 1, 5, 10, 60, 120, and 240 days after shutdown. The spectrum was divided into seven convenient energy groups and each gamma was assigned the mean energy of the group in which it occurs.

The energy group distributions of the gamma decay rates also are included for various times of operation and shutdown. The operating times considered were 10 minutes, 1, 10, 100, 1000 hours, and infinite operation. The after-shutdown times were from 4 hours to 10 days except for the 8 months after-shutdown time for 1000-hour operation.

The total decay rates check very well with the Way-Wigner expression:

$$\Gamma(\text{Mev sec}^{-1}/\text{fission}) = 1.26\tau^{-1.20} \qquad 10 < \tau < 10^{7}$$

where τ is the time after fission in seconds

All the results of this study were made applicable to any thermal reactor using U^{235} by expressing the activities as percentages of saturation activity and by normalizing the results to 1 watt of reactor power.

APEX-218

RADIOLOGICAL EDUCATION AND TRAINING PROGRAM,
Industrial Hygiene, Aircraft Nuclear Propulsion Department, General Electric Company,
(1955), 28 pp.

This publication explains the methods and materials employed by the Industrial Hygiene unit in the education and training of ANP department employees. This report outlines the seven general phases of this training program. These phases are orientation, P-approved contact, Q-cleared contact, periodic follow-up discussions, visual education, distribution of printed material, and special education and training.

ASAE-5

Nowak M J
EFFECTIVENESS OF REACTOR CONTROL ABSORBERS SENSITIVE TO NEUTRONS OF ALL ENERGIES,
American Radiation and Standard Sanitary Corporation, Redwood City, California, February 1, 1957, 31 pp.

A criterion is established for the effectiveness of a reactor control absorber sensitive to neutrons of all energies from fission to thermal. This criterion can be used to determine an optimum alloy of absorber material, dependent on the absorption parameters of the elements and the slowing-down properties of the medium in which the absorber is used.

The analysis is based on multigroup diffusion theory. The effectiveness of an absorber is defined as the change in power output (as measured by thermal neutron content) produced by insertion of the absorber into an infinite uniform source medium having the same flux spectrum as the reactor in which the absorber is used. The same criterion can also be derived from perturbation theory.

This effectiveness criterion describes the intermediate case between the limiting conditions of weak absorbers and black absorbers, which are known from simpler theory.

BMI-174-QPR-1

Diethorn W S, et al.
NEUTRON DOSIMETRY RESEARCH,
First Quarterly (March 15 to June 14, 1957) Progress Report to US Army Signal Engineering Laboratories, Belmar, New Jersey, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, June 30, 1957, 16 pp. (15 refs).

This report presents a survey of neutron dosimeter systems (semiconductor, tissue-equivalent ionization chambers, and chemical recoil-proton systems), discusses future plans for work on ionization chamber and chemical systems, and outlines a research program on semiconductors.

BMI-174-QPR-2

Diethorn W S, et al.
SECOND QUARTERLY PROGRESS REPORT ON NEUTRON DOSIMETRY RESEARCH,
US Army Signal Engineering Laboratories, Belmar, New Jersey, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, Contract No. DA-36-039-SC-73174, October 2, 1957, 16 pp. (14 refs).

During this quarter, the examination of important semiconductor literature was continued and the theoretical analysis of lifetime phenomena in silicon and germanium extended. Experimental work was initiated to determine the relationship between neutron dose and lifetime changes in these materials. Preliminary experiments were completed on single crystals of AlSb, CdTe, and InP, as part of the study to determine the application of these high-energy-gap compound semiconductors to neutron dosimetry based on conductivity changes. Although the specimens used in these latter experiments were not optimum, the experimental results indicate that these materials have promise for the Signal Corps dosimeter application.

The paper study of ionization-chamber theory and performance is under way. Second-quarter activities in this area were concentrated on the literature aspects of this subject. The major effort in the initial stage of this study will be an analysis of ion recombination and the effect of this phenomenon on ionization-chamber performance.

Some effort during this quarter was devoted to a search for new approaches to neutron dosimetry.

BMI-1083

Smith Charles K, et al.
THE DEVELOPMENT OF A THERMAL-NEUTRON-FLUX MEASURING INSTRUMENT, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, Contract No. W-7405-Eng-92, April 12, 1956, 15 pp.

An instrument was developed to measure thermal neutron flux directly and automatically in the range from 10^{13} to 10^{14} neutrons/(cm^2)(sec) at ambient temperatures up to 600°F. Two prototype tests were conducted. Measurements made with this instrument are independent of gamma flux and, within a small error, independent of ambient temperature. The method depends on balancing the temperatures of an electrically heated balancing element and a fission-heated uranium-fueled sensing element. Thus, the instrument gives a direct measurement of fission-product power, produced by a known amount of uranium.

The flux-detector assembly measures 3/16-in. in OD by about 4 in. in length and is fitted with an extension so that it is movable over a 20-ft length inside a 0.210-in. ID tubular well in the reactor.

Two tests of the prototype instrument were conducted by making vertical traverses of the flux field in the beryllium reflector of the MTR. Measurements were made in 1-in. increments from 16 in. above to 5 in. below the center line of the core. Instrument response time was about 1 minute for each measurement. The maximum deviation of a single instrument reading from the average readings at a given point was about 2.5% at a flux of 10^{14} neutrons/(cm^2)(sec).

An appendix is included which outlines the method used to fabricate the balancing and sensing elements in this instrument.

BMI-1086

Klickman Alton E, et al.
A WIRE-ACTIVATED TECHNIQUE FOR REACTOR-FLUX-PROFILE MEASUREMENTS, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, Contract No. W-7405-Eng-92, April 25, 1956, 14 pp. (8 refs).

The application of the wire-activation technique was extended so that flux profiles could be obtained in a reactor core where the flux is of the order of 10^{14} neutrons/(cm^2)(sec) and the ambient temperature is about 600°F.

A magnesium-0.01 a/o indium wire 0.010 in. in diameter was investigated. The wire is irradiated first in a 0.170-in. OD by 0.110-in. ID magnesium tube and then in a magnesium-33 a/o cadmium tube of the same size. Thus, it is possible to obtain both the thermal and slowing-down flux profiles quite rapidly.

To prove the feasibility of the method, in-pile tests were conducted at CP-5. Ten 10-in. wires were irradiated in magnesium tubes and ten 10-in. wires in magnesium-33 a/o cadmium tubes. The irradiation time was 30 minutes. After a 1-hour period to allow the decay of extraneous activities, the wire was run past a collimated scintillation counter. The counter sees 1-in. sections of the wire which it counts for 15 seconds each. A mechanism records the counts and then moves the wire 1-in. for the next counting period.

Tests with the magnesium-0.01 a/o indium wire showed that the method was feasible and the counting rates were high enough to give reliable results. Some specimens of cobalt and magnesium-0.1 a/o manganese were also exposed in the CP-5. It was hoped that materials with different resonance absorption peaks could be used to give an energy spectrum. However, the cobalt wire proved unsatisfactory because of impurities and the magnesium-0.1 a/o manganese gave counting rates which were too low.

BNL-171 ATI-156088

CONFERENCE ON FISSION PRODUCT UTILIZATION,
February 18-19, 1952, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York, 45 pp.

This document contains papers covering two topics: (1) Dosimetry in Intense Radiation Fields, and (2) Progress in Fission Product Application.

Under topic (1) the following papers were given:

A. Some Problems in Chemical Dosimetry
B. A Calorimetric Calibration of Gamma-Ray Actinometers
C. A Methylene Blue Dosimeter
D. Development of a Polyvinyl Film Dosimeter
E. Radiation Dosimetry with Crystal Conduction Dosimeters

Under topic (2) the following papers were given:

A. Irradiation of Bacteria, Yeasts, and Molds
B. Food Preservation by Irradiation and Associated Studies
C. Initiation of Chemical Reactions
D. The Effects of Gamma Radiation on Bacteria, Molds, Yeasts, Vitamins and Enzymes
E. Irradiation of Food and Initiation of Chemical Reactions
F. Initiation of Chemical Reactions
G. Progress at BNL on Industrial Applications of Intense Gamma Radiation
H. Progress at Stanford Research Institute
I. Progress at GE Engineering Laboratory

BNL-344

Weiss Max M
AREA SURVEY MANUAL,
Brookhaven National Laboratory, Upton, New York, June 15, 1955, 148 pp.

This report was prepared to describe the instrumentation for the area radiation monitoring stations established by Brookhaven National Laboratory. It also serves as an instruction book for the operation and maintenance of these stations. These stations provide the legal protection necessary to an operation of this nature.

The equipment contained in each station includes: a photographic assembly for permanent records, several Geiger-Mueller counter assemblies, a battery operated rate-meter assembly, a dynamic condensor electrometer-ionization chamber, an air sampler, several integrating ionization chambers, natural radiation background measurements, and effects upon background of pile operations.

BNL-358 (T-66)

Bloom S D, Reilly E and Toppel B J
A HIGH PRESSURE PROPORTIONAL COUNTER FOR FAST NEUTRON SPECTROSCOPY,
Brookhaven National Laboratory, Upton, New York, June (1955), 11 pp.

A high pressure proportional counter has been built for use as a fast neutron spectrometer. The sensitive cylindrical volume defined by field tubes is 10 cm in diameter by 14 cm long. The counter is normally operated at voltages of 6000-8000 volts with pressures of from 6 to 10 atmospheres. Fillings of argon, helium, and krypton have been successfully used. The use of a graphite liner on the cathode improves the resolution by a factor of three and eliminates the need for counter degassing. The $He^3(n, p)T$ reaction using thermal neutrons yields a resolution of 4.5%. The counter has been used to study the $A^{36}(n, a)S^{33}$ reaction and to detect He^3 in normal tank helium.

BNL-386 (T-72)

Handloser J S and Delihas N
GAMMA-RAY NEUTRON DOSIMETRY OF THE BIOLOGY NEUTRON IRRADIATION FACILITY,
Brookhaven National Laboratory, Upton, New York, November (1955), 10 pp. (13 refs).

Measurements of neutron flux and energy distribution and gamma-ray intensities were made in the thermal column of the Brookhaven reactor. The thermal neutron flux was measured with gold foils; resonance neutrons with copper wire; fast neutrons with Pu, U, and S threshold detectors; and gamma intensity with a carbon ionization chamber. Measurements were made for the empty thermal column, the thermal column with a U^{235} converter plate, and the instrument tunnel. Results of all measurements and experimental details are presented.

BNL-433 (C-24)-1

Sher R and Kouts H J
THE EFFECT OF EPITHERMAL FISSIONS ON THE NEUTRON CYCLE,
Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, Brookhaven National Laboratory, Upton, New York, September 24-25, 1956, 4 pp. (6 refs).

The usual formulations of the neutron cycle and the critical equation in a thermal reactor neglect the contribution to the neutron economy of epithermal fissions in U^{235}, although several methods of accounting for these exist in the literature. The

group-diffusion equations are examined from the point of view of absorption probabilities, rather than escape probabilities, and a critical equation is derived in terms of f, η, and several experimentally measurable quantities. Then ε and ρ can be somewhat arbitrarily defined so as to make our critical equation have the form of the four-factor formula.

BNL-433 (C-24)-2

Niemuth W E
MEASUREMENTS OF RESONANCE ESCAPE PROBABILITY IN HANFORD LATTICES,
Hanford Atomic Products Operation, Richland, Washington. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 9 pp. (11 refs).

Techniques of gamma-ray scintillation spectroscopy have been used to determine radial distributions of "thermal" neutrons and plutonium build-up in natural uranium fuel elements in Hanford lattices. Pin detectors of U^{238} and U^{235} of approximately 0.060-in. diameter and 0.250-in. length were fitted into a section of fuel element and into the graphite and irradiated in the Hanford piles. Cadmium ratios served to separate the distributions into thermal and epicadmium components. Interpretation of these distributions in light of the formula

$$\frac{1}{\rho} = 1 + Rf\left(\frac{\Sigma_{a28}}{\Sigma_{a28} + \Sigma_{a25}}\right)$$

which may be derived from a basic definition of resonance escape probability yields the desired results. Here R is the measured ratio of resonance to thermal captures in U^{238}, f is the measured lattice thermal utilization, Σ_{a28} and Σ_{a25} are macroscopic absorption cross sections for U^{238} and U^{235} respectively, and ρ is the resonance escape probability. Comparisons of experimental results with calculations based on handbook formulas indicate that measured values of ρ are approximately 3% smaller than calculated values. The techniques employed to obtain and analyze the data are discussed.

BNL-433 (C-24)-3

Hansen G E and Roach W H
INTERPRETATION OF NEUTRON RESONANCE DETECTOR ACTIVATIONS IN CRITICAL URANYL FLUORIDE - HEAVY WATER SOLUTIONS,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 13 pp. (5 refs).

Activation measurements with In, Au, Co, and Mn in a series of critical $U^{235}O_2F_2$ heavy water solutions indicate flux spectra markedly influenced by the resonance character of the U^{235} absorption cross section in the 2 to 200-ev energy range. These spectra appear to be consistent with the U^{235} resonance parameter data given in BNL-325.

BNL-433 (C-24)-5

Hellstrand E
MEASUREMENTS OF NEPTUNIUM ACTIVITY IN IRRADIATED URANIUM RODS,
Aktiebolaget Atomenergi, Stockholm, Sweden. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 1 p.

The spatial distribution of the resonance absorption of neutrons in uranium rods has been determined by peeling off successive layers of irradiated rods and measuring the neptunium activity. The rods ranged from 8 to 50 mm in diameter. (J.C.)

BNL-433 (C-24)-6

McMillan D E, et al.
MEASUREMENTS OF ALPHA OF URANIUM-233,
Knolls Atomic Power Laboratory, Schenectady, New York. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 5 pp. (3 refs).

Alpha of U^{233} has been measured by Hanford pile exposures of samples surrounded by various shields to cut out the low energy neutrons at various energies. The fissions induced in the samples were determined from measurement of the activities produced by fission products Cs^{137} and Ce^{144}. The radiative captures were determined from mass spectrometer measurements of the U^{234} to U^{233} ratio. The following results were obtained:

Cutoff Energy of Shield	Alpha of U^{233}
No Shield	0.10
0.2 ev	0.15
0.5 ev	0.18
30.0 ev	0.14

BNL-433 (C-24)-7

Spinrad B I
INTERPRETATION OF EXPERIMENTS ON RESONANCE INTEGRALS,
Argonne National Laboratory, Lemont, Illinois. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 3 pp. (9 refs).

The theory and analysis of integral experimental methods for evaluating resonance integrals are presented. The relative precisions of lattice fitting activation and direct measurement of resonance escape are compared and the corrections which must be made to data derived from the various methods are illustrated. Several self-consistent models of the neutron conservation processes are compared with regard to the applicability of resonance data obtained by the various methods.

BNL-433 (C-24)-8

Klein D, et al.
MEASUREMENTS OF RESONANCE ESCAPE PROBABILITY IN 1.3 PERCENT ENRICHED URANIUM AND URANIUM OXIDE FUELED LATTICES,
Westinghouse Electric Corporation, Bettis Plant, Pittsburgh, Pennsylvania. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 5 pp.

Resonance escape probability measurements have been made in slightly enriched uranium and uranium oxide, light water moderated lattices. These measurements have been made at several water-to-metal ratios and two rod sizes. Experimental results will be presented and compared with theoretical calculations.

BNL-433 (C-24)-10

Mummery P W
CORRELATION OF INTEGRAL EXPERIMENTS WITH LATTICE CALCULATIONS,
Atomic Energy Research Establishment, Harwell, Berkshire, England. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 3 pp. (3 refs).

Systematic integral experiments can be correlated with a method of lattice calculations in order to deduce slowing-down area, fast fission factors, effective resonance integral, and neutron yield from fissile material. Results are reported for experiments in graphite, natural water, and heavy water moderators. Satisfactory agreement can be obtained between the graphite and natural water results, and the U^{235} neutron yield deduced is in satisfactory agreement with the accepted value.

BNL-433 (C-24)-11

Corngold N
THE EFFECT OF FINITE FUEL MASS ON RESONANCE ABSORPTION IN SLAB LATTICES,
Brookhaven National Laboratory, Upton, New York. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 5 pp. (2 refs).

A comparison of the absorption at various resonances in a typical uranium-water lattice has been made for the cases $M_U = 238$ and $M_U \to \infty$. The slowing-down equations used are those previously given by Chernick and by Corngold. Analysis yields a simple criterion for the determination of the accuracy of the infinite-mass formula for any particular resonance.

BNL-433 (C-24)-12

Oleksa S
THE EFFECTS OF THE FLUCTUATIONS OF NUCLEAR REACTION WIDTHS ON $\bar{\sigma}(n,\gamma)$, $\bar{\sigma}(n, f)$ and α,
Brookhaven National Laboratory, Upton, New York. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 9 pp. (13 refs).

It has been shown by Wigner that it is possible to calculate the variation of $\bar{\sigma}(n, \gamma)$, $\bar{\sigma}(n, f)$, and α as a function of energy in the range 100 ev to 10,000 ev by considering the fluctuations of the neutron scattering widths and fission widths of the resonance levels below 100 ev. This has been done for U^{235} The effects of fitting the experimental data with several different distributions will be shown.

BNL-433 (C-24)-13

Wigner E P
REVIEW OF RESONANCE CAPTURE BY LUMPS,
Princeton University, Princeton, New Jersey. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 6 pp. (13 refs).

In this address, given at the invitation of the conference, Wigner reviews the United States and Russian work on resonance absorption of uranium in bulk. The close agreement between the US and USSR formulas for the effective resonance integral of metallic uranium over the range of practical interest is demonstrated. The differences in the theoretical formulations are discussed as well as their effect on calculations of resonance capture in uranium oxide lattices. The importance of reassessing the effect of the latest resonance constants on the various energy regions of the resonance absorption is pointed out. (J.C.)

BNL-433 (C-24)-14

Triplett J R
THE EFFECT OF EPITHERMAL AND RESONANCE CAPTURE IN HETEROGENEOUS SYSTEMS,
Hanford Atomic Products Operation, Richland, Washington. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 2 pp. (2 refs).

Calculation results are presented which illustrate the effects of extended irradiation upon epithermal absorption and fission in a heterogeneous lattice, as well as upon the thermal parameters. The Goertzel-Greuling slowing-down kernel is employed. Absorption in the fuel is treated by the blackness theory which neglects slowing down in uranium. Nine heavy isotopes and one fission product group are represented in the calculation, although cross sections are not adequately known for most of these. Chief emphasis has been placed on development of a flexible IBM program, which can be used to compare cross-section information directly with the results of high-exposure integral experiments.

BNL-433 (C-24)-15

Safonov G
RESONANCE ESCAPE PROBABILITY IN NATURAL URANIUM AND LIGHT AND HEAVY WATER MIXTURES,
Rand Corporation, Santa Monica, California. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 3 pp.

The resonance escape probability for natural uranium in aqueous mixtures has been obtained as part of a broad theoretical survey of homogeneous water-uranium reactors. Results of multigroup calculations are presented for various mixtures of H_2O and D_2O and for water-to-uranium molar ratios ranging from 10^{-2} to 10^4. (J.C.)

BNL-433 (C-24)-19

Dresner Lawrence
THE EFFECT OF GEOMETRY ON RESONANCE NEUTRON ABSORPTION IN URANIUM,

Oak Ridge National Laboratory, Oak Ridge, Tennessee. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 6 pp. (11 refs).

A simple theoretical expression has been derived for the geometric dependence of the effective resonance integral of uranium which is independent of the details of resonance structure. Comparison with experiment yields good agreement when the surface absorption is reduced arbitrarily to 60% of its theoretical value.

BNL-433 (C-24)-20

Spinney K T
RESONANCE ABSORPTION IN HOMOGENEOUS MIXTURES,
Atomic Energy Research Establishment, Harwell, Berkshire, England. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 7 pp. (1 ref).

The problem of calculating resonance absorption probabilities in homogeneous mixtures of U and H is discussed. Quantitative results are presented of the absorption in individual U resonances made with two approximate methods (the narrow resonance and the narrow resonance with infinitely heavy absorber), and these are compared with numerical solutions of the exact expression. The calculations, which are for a 1:1 atomic ratio, make use of experimental data now available for the first 18 resonances in U and include the effect of Doppler-broadened cross sections. Other tables are shown for a 10:1 H to U ratio and also the results of a new "modified" narrow resonance approximation which is found to give considerably greater accuracy over most of the energy range.

BNL-433 (C-24)-21

Neumann H
RESONANCE ESCAPE PROBABILITY IN REACTOR LATTICES,
Hanford Atomic Products Operation, Richland, Washington. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 6 pp. (17 refs).

For a lumped-fuel lattice reactor, the probability that a neutron escape capture during the slowing-down process by an isotope with isolated resonances may be shown to be approximately

$$P(u) = \exp\left[-(S/4\varepsilon\Sigma_s V_m)\int_o^u \beta(u')du'\right]$$

where S = lump surface area, ε = mean logarithmic energy decrement for moderator collisions, Σ_s = moderator macroscopic scattering cross section, V_m = moderator volume per fuel lump, u = neutron lethargy, and $\beta(u)$ = lump blackness (capture probability for neutrons entering the lump). The blackness is a function only of lump materials, temperature, and geometry.

Temperature-broadened absorption and scattering cross sections, including scattering interference asymmetry terms, have been generated for 18 known resonances of U^{238}. Assuming that uranium does not moderate, ρ has been calculated for 14 graphite-natural uranium rod lattices for which exponential pile experimental data exist.

It is concluded that, for fuel rods 1.36 inches in diameter, these 18 resonances account for at least 60% of the total resonance capture, over a factor of four ranges in V_m. The results further suggest that the spatial distribution of the collision density in the moderator is fairly flat at resonance energies.

BNL-433 (C-24)-22

Stein S
RESONANCE ABSORPTION BY URANIUM-238 IN SLIGHTLY ENRICHED URANIUM-WATER SYSTEMS - THEORETICAL METHODS IN USE AT BETTIS,
Westinghouse Electric Corporation, Bettis Plant, Pittsburgh, Pennsylvania. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 3 pp.

A model is described for calculation of resonance escape probability in a variety of light water moderated metal fuel reactor lattices. The results are correct to first order in the resonance width. By means of additional approximations, a simple analytic scheme is obtained exhibiting the main features of the problem, and in good agreement with the results of Monte Carlo calculations.

BNL-433 (C-24)-23

Chernick J
STUDIES OF NEUTRON CAPTURE IN URANIUM-238 RESONANCES,
Brookhaven National Laboratory, Upton, New York. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 6 pp. (8 refs).

General formulas are obtained for resonance absorption in a lattice cell in terms of escape probabilities. The formulas are discussed for widely spaced resonances in the limit where the practical width of the resonance is either much smaller or much larger than the maximum energy loss in uranium collisions. The importance of interaction effects in tight lattices is shown by Monte Carlo calculations. Other Monte Carlo results yield the differential effects of uranium and oxygen moderation in water moderated uranium and uranium oxide rod lattices. The results are compared with those obtained for slabs and homogeneous mixtures.

BNL-433 (C-24)-24

Weinberg Alvin M and Wigner E P
A SECOND-ORDER CORRECTION TO THE USUAL RESONANCE ESCAPE FORMULA
Oak Ridge National Laboratory, Oak Ridge, Tennessee; Princeton University, Princeton, New Jersey. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 2 pp. (1 ref).

The slowing-down equation for the neutron flux in a homogeneous, absorbing moderator is transformed into an integral equation involving the so-called Placzek function. To a first order, the solution is given by the usual approximation. By iteration, a second-order correction to the resonance escape formula is obtained.

BNL-487

Daniels Elaine
TABLE OF RADIOISOTOPES ARRANGED ACCORDING TO HALF-LIFE,
Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York, December (1957), 55 pp.

The data (on half-life of radioisotopes) in this table were taken directly from the General Electric Chart of the Nuclides, Fifth Edition. Great care was taken in copying the table data and in proof-reading the copy to eliminate errors in transcription.

CC-648

Compton A H (Project Director)
CHEMICAL RESEARCH - RADIATION CHEMISTRY - REPORT FOR MONTH ENDING MAY 15, 1943,
Metallurgical Laboratory, May 15, 1943, 21 pp.

Information has been obtained on the effect of β and γ radiation on the electrical resistance of insulating materials. The results are summarized. The recovery to original resistance values has been measured. In general, the initial rate is rapid for the first few hours; the rate then decreases sharply. Certain samples show evidence of complete recovery. Effects on mechanical properties of several plastics have also been studied.

Data on gas evolution from several organic materials including those suggested by the physiological shield have been extended to include both β and deuteron bombardments. Samples of "Press-wood" are being evaluated.

The effect of current on the H_2O_2 production in water containing I- has been studied at several I- concentrations. Water contain-dissolved CO_2 shows the presence of oxidant (presumably H_2O_2).

H_2O_2 has been produced by recoil protons from the scattering of fast neutrons in deoxygenated water.

Radioactive solutions do not greatly affect the applicability of the glass electrode providing the electrode is thoroughly washed with distilled water before immersion in the standard buffer solution.

CEP-0658-1

Henley E J, et al.
SCALE...OF RADIATION EFFECTS,
Chemical Engineering Progress, Vol. 54, No. 6, pp. 69-72, June (1958), (12 refs).

The effects of atomic radiation on chemical systems are a function of the rate and mode of energy transfer. Some important investigations have been made to determine the relationship between radiation effects and rate of energy transfer. Some of these are discussed in this paper.

CF-51-5-61

Cochran R G and Hungerford H E
FAST NEUTRON DOSIMETER MEASUREMENTS FOR EXPERIMENT #1 IN THE BULK SHIELDING FACILITY,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, May 7, 1951, 6 pp. (3 refs).

This document discusses fast neutron dosage measurements taken in water to nearly 170 cm with the Bulk Shielding Facility dosimeter. Also discussed are several experimental difficulties encountered during the experiment. A curve is included showing fast neutron dosimeter centerline measurements for the Bulk Shielding Facility.

CF-51-5-164

Hill John W, Jr.
NEUTRON FLUX MEASUREMENTS IN THE BULK SHIELDING FACILITY REACTOR,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tennessee, Contract No. W-7405-Eng-26, May 15, 1951, 33 pp.

Neutron flux distributions have been measured in the BSF Reactor with gold foils to provide data for a calculation of the reactor power level. Only the location of fuel and reflector pieces are shown. Three different lattice arrangements were investigated and are shown in three figures. Horizontal and vertical traverses were made through the lattice in representative positions. All the data taken are shown in tables, while representative traverses are plotted as saturated activity versus distance.

CF-51-7-75 SERM-94

Muckenthaler F J and Henry Keith M, Jr.
NEUTRON ENERGY SPECTROMETER,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 16, 1951, 3 pp.

This is a brief document which presents data taken with the coincidence counter for the proton recoil-type neutron spectrometer in the thermal column of the X-10 ORNL pile, without a lead shield surrounding the counter.

CF-51-8-215

Eister W K
THE TREATMENT OF RADIOACTIVE WASTES,
Chemical Technology Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tennessee, August (1951), 9 pp.

The proper treatment and disposal of radioactive wastes represents a problem of major concern to the AEC program. These radioactive wastes result from raw materials processing, isotopic separations, nuclear reactor operations, reactor product processing, and development objectives of the AEC for the proper treatment and disposal of radioactive waste is personnel safety.

This paper discusses control of radioactive waste disposal and general waste disposal procedures for liquid waste, gaseous wastes, and solid wastes.

CF-51-11-96

Hungerford H E and Cochran R G
FAST NEUTRON MEASUREMENTS AT THE BULK SHIELDING FACILITY,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, December 10, 1951, 11 pp.

This report presents and discusses data obtained as a result of two independent sets of measurements of fast neutrons; the first by means of a radioactive threshold detector and the second by means of a U^{238} fast fission chamber. The data were obtained along the centerline in water at various distances from the BSF.

CF-52-3-219

Blizard E P
TRANSFORMATION FROM DISC TO POINT SOURCE GEOMETRY,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 27, 1952, 2 pp.

It is often useful to transform from data taken along the axis of a uniform circular source to what would be expected from a point source. The usual method has been to apply a Hurwitz transformation followed by differentiation. An analogous method is here presented in which the convergence should be somewhat better. Further the differentiation is applied directly to the data, rather than to the transformed data, affording somewhat better accuracy to the use of the method.

CF-53-6-1 (Rev)

Blosser T V and Hullings M K
DECAY GAMMA-RAY DOSE RATE MEASUREMENTS AT THE BSF,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 12, 1955, 6 pp. (3 refs).

Measurements of decay gammas from the Bulk Shielding Reactor have been made to determine the exposure to which the operating personnel will be subjected with several depths of water over the reactor. Experimental procedure and results are discussed. The conclusions reached are that an analysis of the data will enable a determination of the necessary water shield for this reactor for a given radiation level at various times after shutdown.

CF-55-10-140

Trice J B
A SERIES OF THERMAL, EPITHERMAL AND FAST NEUTRON MEASUREMENTS IN THE MTR,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, Contract No. W-7405-Eng-26, October 28, 1955, 88 pp.

A series of neutron flux measurements using resonance reactions, np and $n\sigma$ reactions, and threshold energy fission reactions, were performed in one of the horizontal beam holes (HB-3) in the MTR. It was shown that the maximum flux above thermal energy is $(3.1 \pm 0.6) \times 10^{13}$ neutrons $\cdot$ cm^{-2} $\cdot$ sec^{-1}, and that the thermal flux maximum is $(2.3 \pm 0.4) \times 10^{14}$ neutrons $\cdot$ cm^{-2} $\cdot$ sec^{-1}.

Two separate instrument development programs are described. One is the design construction and operation of a pneumatic facility for very rapid and safe transfer of materials into and out of the high level neutron field, and the other is the development of a series of very small fission chamber probes using threshold fission reactions in very intense radiation fields. Attempts to express results as crude neutron spectra are described.

The threshold reaction $Ni^{58}(np)Co^{58}$ was investigated for use as a radiation damage monitor for metals. It was concluded that more information is needed in regard to the reaction cross section before it can be approved for such service.

CF-56-3-72

Binford F T, Bettis E S and Howe J T
GAMMA HEATING MEASUREMENTS IN THE BULK SHIELDING REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 7, 1956, 20 pp. (6 refs).

A series of experiments to determine the rate of gamma heating in construction materials in the vicinity of a reactor core of the MTR type were carried out in the Bulk Shielding Reactor at the Oak Ridge National Laboratory. The method used employed measurement of the transient temperature of the samples during heating in the gamma field and cooling after removal from the gamma field. Results suitable for use in connection with the engineering design of reactor structures were obtained using aluminum, lead, iron, and copper samples.

CF-56-5-76

Murray R B and Schenck J
SCINTILLATION RESPONSE OF LiI(Eu) CRYSTALS TO MONOENERGETIC FAST NEUTRONS,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tennessee, May 11, 1956, 12 pp.

The scintillation response of LiI(Eu) crystals to monoenergetic fast neutrons has been investigated in the course of a study directed toward the development of a more versatile and efficient fast-neutron spectrometer. The scintillation response has been determined as a function of neutron energy (in the range 0.63 to 14.9 Mev), Eu concentration, Li isotope concentration, and crystal temperature. The pulse height spectra of those crystals containing Li^6 demonstrate a peak from the fast neutron induced $Li^6(n,\alpha)t$ reaction. At room temperature the peak from fast neutrons of energies less than 6 Mev is broad and roughly rectangular in shape. A substantial improvement in the shape and resolution of the fast-neutron peak is found, however, on cooling the crystals to about $-140^{\circ}C$.

CF-863

Ashkin J and Feld B
ACTIVATION OF FAST NEUTRON DETECTORS BY CYCLOTRON AND BY FISSION NEUTRONS,
Metallurgical Laboratory, Oak Ridge National Laboratory, Oak Ridge, Tennessee,
April 1, 1943, 8 pp.

The (n, α), (n, p) and (n, γ) reactions in Al, P and I have been studied as fast neutron detectors, by investigating their activation in a pile of U metal. The cyclotron was used as a source of fast neutrons. Two categories of neutrons were considered: "fast," or those capable of exciting (n,α) and (n, p) reactions, and "slow," or those exciting (n,γ) activities.

(a) The relative activations of these reactions were studied in different parts of the pile. For "fission" neutrons, the ratio of activities was found to be:

$$\frac{Al(n,\alpha)}{Al(n,p)} \simeq .4; \qquad \frac{Al(n,p)}{P(n,p)} \simeq .2; \qquad \frac{I(n,\gamma)}{Al(,\alpha)} \simeq 7.$$

These results suggest a method of comparing the fission spectrum with the energy spectrum of other sources by comparing activations of fast neutron detectors.

(b) Information, on the way in which cyclotron neutrons come into equilibrium in the metal, is gained by considering the variation in relative activation for different positions in the pile.

(c) The experimental "slow" to "fast" ratios are directly compared with the capture to fission ratios observed by Snell and reported in CF-589. It is shown that the $\left(P(n,\gamma)/P(n,p)\right)$ ratio behaves in somewhat the same fashion as uranium capture/fission.

COO-104

RADIATION DAMAGE RESEARCH
Second Quarterly Report - October 1 to December 31, 1952, Purdue University, Lafayette, Indiana, Contract No. AT-(11-1)-125, March 31, 1953.

This document contains four reports. These are:

1. Goff, James, "The Thermal Conductivity of Germanium Semiconductors at Low Temperatures"
2. Klontz, E E, "Resistance Changes in Germanium Single Crystals During Electron Bombardment"
3. Harman, T C, et al., "Hardness of Deutron Irradiated Molybdenum"
4. Binnie, W P and Liebschutz, A M, "An X-Ray Study of Radiation Damage in Single Crystals"

CP-2245

Sturm W J and Dabbs J
A SENSITIVE PARTICLE IONIZATION CHAMBER FOR NEUTRON DETECTION,
Oak Ridge National Laboratory, Oak Ridge, Tennessee, Contract No. W-7401-Eng-37, November 21, 1944, 19 pp.

A particle ionization chamber of sensitivity sufficient to detect a source of one neutron per second has been used to measure the neutron yield from a thick target of sulfur upon bombardment with polonium alpha particles. The high-geometry boron trifluoride

chamber used had an efficiency of 1.9% for fission neutrons. The neutron yield from a thick target of sulfur was measured by this instrument and found to be 0.0035 ± .0013 neutrons per million incident polonium alpha particles.

CP-2261

Nedzel V Alexander
A METHOD FOR NEUTRON ENERGY MEASUREMENT,
Metallurgical Laboratory, Clinton Laboratories, October 18, 1944, 10 pp.

This report discusses a method proposed to measure neutron energies by accurately determining the momenta of recoil protons in a magnetic spectrometer specially designed for this purpose. The main consideration in the design of the spectrometer is the shielding of the detector from the high radiation background associated with intense neutron beams.

CVAC-238T FZK-9-080

Hessee E V
GTR DOSE RATE DISTRIBUTION MEASUREMENTS IN WATER,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, April 20, 1955, 101 pp. (9 refs).

Radial fast neutron and gamma dose rate mapping of a single octant of the Convair Ground Test Reactor in water has been performed with constant detector orientation. Data were taken at 50, 70, 90, and 110 centimeters from the center of fuel along 18 radial lines and from these plots isodose curves have been constructed. These plots indicate that the isodose surfaces are not spherical for the region investigated, but have more of an ellipsoidal appearance. In the horizontal plane, at a radial distance of 50 centimeters the gamma dose rates vary by a factor of 1.5 and the fast neutron dose rates by a factor of 3. A comparison of the radials corresponding to the north and west centerlines with respect to distance from the reactor face shows that the difference in fuel distribution makes little difference in the dose rate values. For other radials not normal to a reactor face the differences are appreciable. The effect of the fuel element grid plate displacing water below the core is evident from a comparison of fast neutron and gamma isodose plots.

Symmetry checks show that the GTR is approximately symmetrical about the east-west, and north-south planes and slightly asymmetrical about the horizontal midplane.

Comparison of BSR-GTR centerline fast neutron dose rate data shows the latter to be higher by approximately 15%; agreement between the two curves on the basis of relaxation lengths is good.

Comparison of centerline gamma dose rates for the two reactors is not as favorable. GTR gamma data is approximately 20% lower close to the reactor north face and crosses over at about 80 centimeters becoming slightly higher further out. GTR gamma data were taken with three different gamma instruments with consistently good agreement in regions of overlapping sensitivity.

GTR and BSR centerline thermal neutron flux values agree within approximately 5% from 15 to 150 centimeters separation distance from the reactor face. The thermal flux at the center of the GTR north face from gold foil data agrees within 4% with

BSR indium foil data at that point. The GTR curve from 1 to 15 centimeters is weak because of insufficient foil exposures in that region.

DP-234

Weisner L E, Jr.
TRANSISTOR NEUTRON COUNT RATE METER,
Engineering Assistance Section, Works Technical Department, Savannah River Plant,
E. I. duPont de Nemours and Company, Contract No. AT-(07-2)-1, August (1957), 11 pp.

An all-transistor neutron count rate instrument has been developed for use with a boron trifluoride counter. This instrument is inexpensive, highly reliable, and requires less maintenance than its vacuum-tube counterpart. This report discusses the instrument in detail.

DPI-CML-3617-FR/53 AD-7152

EVALUATION STUDIES OF COLORIMETRIC AND CONDUCTIMETRIC DOSIMETERS,
Final Report to Chemical Procurement Agency, Distillation Products Industries, Rochester, New York, Contract No. DA18-108-CML-3617, April 15, 1953, 6 pp.

The contract objectives are reviewed and compared with the accomplishments. The conductimetric and the colorimetric dosimeters have been studied for sensitivity, stability, dose rate dependence, and after radiation. It was found that both dosimeters possess practically the same sensitivity and are usable in the range 50 to 600 r. The cost of manufacture of each type dosimeter is approximately the same. A section is devoted to remarks on the radiation reaction in chloroform. The significance of the experimental results to the theory of the reaction mechanism is discussed.

Faraday-5

Seitz, Frederick
ON THE DISORDERING OF SOLIDS BY ACTION OF FAST MASSIVE PARTICLES,
Reprint from discussions of The Faraday Society, No. 5 (1949), 20 pp.

Many solid materials undergo extensive changes when exposed to radiations of the various types that are available at the present time. Undoubtedly the most striking and useful effect of this kind that has been studied to date is that observed in the silver halides when they are exposed either to electromagnetic radiations or to the various charged radiations that may be produced. The widespread availability of high-intensity sources of radiations of massive particles as a result of the development of electro-nuclear machines and neutron reactors now makes it possible to extend the field of study to regions that were hitherto closed. This report deals briefly with this subject.

Specific topics discussed are influence of charged particles passing through matter, elastic collisions, and excitation and ionization of electrons.

GE-AP-0974

Ruehle William G, Jr.
THE DETERMINATION OF FISSION PRODUCT GAMMA DOSES,
Atomic Power Equipment Department, General Electric Company, San Jose, California, February 25, 1957, (8 refs).

In this paper arbitrary limits of the general fission source gamma problem are set. Then, by assuming cooling of at least one day, it is shown that only 12 different fission product gamma sources need ever be considered. It is quickly seen that of these 12 pertinent gamma sources, the dose from only a few must be calculated to obtain a reliable total dose for any specific problem. A formula is given, detailing the procedure for calculating the total dose. Graphic and tabular data are presented for all the pertinent fission products, and for their yields for the three more commonly used fission sources, uranium-235, plutonium-239, and americium-241. By the use of these data, the gamma dose is determined by considering less than 10% of the total of fission products. Assuming the flux and time schedule are accurately known, the shielded fission product gamma dose can be easily prediced by this method with 90% or better accuracy. In addition, the answers will show which nuclides should be removed early in chemical processing to substantially reduce the amount of shielding required.

GEC-AER-0957

Mills J B B, Bryden R D and Hartshorn P F
A FISSION-PRODUCT DETECTION SYSTEM,
GEC Atomic Energy Review, Vol. 1, No. 2, pp.97-104, September (1957).

This paper gives a general description of a fission-product detection system. Also discussed is the mechanical design, sensitivity, and electrical design of the detection system.

HW-27774 (Del)

Raile Milton N
FINAL REPORT - DECONTAMINATION OF 221-224 B PROCESS EQUIPMENT,
Separations Section, Hanford Works, Richland, Washington, April 20, 1953, 11 pp.

This report discusses the need for a decontamination program for recovery of product remaining in the 200 East Area Process vessels. Decontamination procedures are discussed.

The conclusions of this study are that both citrate-caustic and peroxide-caustic solutions are excellent agents for the removal of fission product absorbed on stainless-steel surfaces, but it was not ascertained which is the most effective since the degree of contamination varied at the time the individual flushes were employed. Both solutions are highly recommended for decontamination work, provided weak nitric acid is used to repassivate the stainless steel surfaces after use of the caustic decontamination solutions.

HW-28431

Unruh C M
DECONTAMINATION OF PORTABLE INSTRUMENTS,
Radiological Sciences Department, Hanford Works, Richland, Washington, May 22, 1953, 4pp.

This report discusses decontamination of portable instruments. Some of the reagents tested for decontamination use are listed. Procedures and results are discussed.

HW-29135

Heineman R E
MEASUREMENT OF NEUTRON FLUX SPECTRA INSIDE REACTORS,
Hanford Works, Richland, Washington, August 26, 1953, 10 pp.

The problem of measuring the neutron spectrum inside a reactive lattice in the epithermal resonance and fast regions is discussed in the light of experiments reported in the literature up to the present time. It appears that foil activation techniques, relying upon sharp changes in isotopic cross sections with energy, are the only reliable methods available. These techniques give data which, in general, are neither very accurate nor sensitive. In the resonance region the lack of isotopes having isolated, high cross-section resonances with favorable half-lives leads to a deficiency of experimental data. In the high energy threshold detector region the cross sections of the threshold reactions are not well enough known to give high accuracy. Future work with fission threshold detectors might improve the spectrum in the latter region.

HW-30606

Reddie J S
DETERMINATION OF FILM EXPOSURE BY NEUTRON ACTIVATION OF THE REDUCED SILVER,
Radiological Science Department, Hanford Works, Richland, Washington, January 14, 1954, 5 pp. (4 refs).

The determination of personnel meter badge film exposure by densitometer methods is difficult or impossible when the film density is 3.0 or greater. For Dupont Type 510 film (insensitive), this corresponds to dose values greater than about 50 r and, although this is well above the maximum permissible dose for humans and is far greater than has been recorded for any Hanford employee, it is desirable to have means of measuring such exposures if they should ever be encountered. If the fact of overexposure is known before development, special development methods can be used which result in lower densities; however, the results obtained by this technique are not reproducible. This report is concerned with a method of measuring these grossly-exposed films that have been developed and processed in the normal manner.

HW-31200

Russell J T
AN IDEA FOR A WIDE RANGE NEUTRON FLUX MONITOR FOR HIGH FLUX REACTORS,
Technical Section, Engineering Department, Hanford Works, Richland, Washington, March 22, 1954, 9 pp.

This report is intended to indicate the technical possibility of a neutron flux meter suitable for accurate and continuous indication of power level during all phases of pile operation. Application to automatic operation are discussed. The material presented represents about all that can be said concerning such a neutron flux meter on the basis of present knowledge. Experimental work is required to determine the true attenuation curve which would be obtained in an actual installation.

HW-38198

Parker H M
QUARTERLY PROGRESS REPORT - RESEARCH AND DEVELOPMENT ACTIVITIES, APRIL-JUNE, 1955,
Radiological Sciences Department, Hanford Atomic Products Operation, Richland, Washington, Contract No. W-31-109-Eng-52, July 11, 1955, 31 pp.

This twenty-third quarterly report of the research and development activities of the Radiological Sciences Department, Hanford Atomic Products Operation, includes descriptions of laboratory facilities, research and development progress, biology, tritium absorption and metabolism of reactor effluent radioactive elements, gamma ray dosimetry, beta ray dosimetry, and neutron dosimetry.

IBM-1

Shapiro C S
GODIVA TEST SERIES DOSIMETRY TECHNIQUES,
International Business Machines Corp., Federal Systems Division, Oswego, New York, 22 pp. (15 refs).

A summary of the dosimetry techniques utilized in the IBM GODIVA test series are presented. They include sulfur discs calibrated against plutonium foils to determine integrated neutron flux, and chlorinated hydrocarbon chemical dosimeters to determine the gamma contamination. The neutron and gamma dose rates as a function of time during a GODIVA burst are determined analytically utilizing the reactor kinetic equations of Wimett and Orndoff. A brief discussion of a possible neutron dose-rate measuring device that is gamma insensitive and is applicable for GODIVA type fluxes is presented.

This work is part of a over-all radiation effects program underway at IBM Oswego, which presently is concerned with the effects of very high-rate, pulsed, nuclear radiation in electronic components and materials.

IDO-16056

Forbes S G
CALIBRATION OF MTR NEUTRON SOURCES,
Technical Branch, Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, January 15, 1953, 16 pp.

Two 1/2-gram Ra-Be neutron sources were taken from the MTR to the Los Alamos Scientific Laboratory for calibration in their standard graphite pile. Los Alamos Ra-Be source No. 44 was used as the standard and all Q values are based on the absolute calibration of this source. The MTR sources were calibrated by means of both a BF_3 counter method and an indium foil method. The results of the two methods agree well within the experimental error of 1% and yield source strengths of 5.96×10^6 and 5.70×10^6 neutrons per second for MTR Nos. 1 and 2 respectively. A description of the methods used and the experimental data obtained are given.

IDO-16080

Hogg C H and Lewis R H
MTR FLUX CALIBRATION UNIT,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, May 22, 1953, 18 pp. (8 refs).

A cadmium-covered AGOT graphite pile was built at the MTR site in the Fall of 1951 to furnish a constant thermal neutron flux for standardizing neutron detectors. A Ra-Be neutron source in the base of the column provides the neutrons.

This report describes the standardization of the pile, i.e., determining the neutron flux along the vertical axis as a function of the distance from the source. The standardization is based on the steady-state thermal diffusion equation for a point source of neutrons in a square column of infinite height.

IDO-16095

Webster J W
WEIGHTING FUNCTIONS FOR CALCULATING REACTIVITY PERTURBATIONS IN THE MTR,
Atomic Energy Division, Phillips Petroleum Company, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, May 14, 1953, 24 pp.

Weighting functions are often needed for the purpose of calculating the effect on reactivity of nonuniform changes in the composition of the core or reflector of the MTR. In this report the flux distributions, adjoint flux distributions, and the weighting functions are computed and graphed for the MTR with 3 x 9 array of 140-gram fuel elements and 110-gram shim fuel sections. The calculations are made in the N-S, E-W, and vertical directions using the slab-type geometry, and then the approximation is made that

$$\phi(x, y, z) \alpha \phi(x) \phi(y) \phi(z).$$

The weighting function for pure absorber and the thermal fluxes are compared with experimental results, and the agreement is found to be reasonably good.

The calculated weighting function for pure absorber is compared with that for fuel and they are found to be somewhat different. The absorber statistical weight falls off more sharply for the outer fuel elements compared to the center than does the statistical weight for fuel.

IDO-16102

Hogg C H
GAMMA INTENSITY MEASUREMENT,
Atomic Energy Division, Phillips Petroleum Company, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, May 12, 1953, 6 pp.

The gamma intensity measurements, described in this report, was made in the gamma facility at the MTR site with a gamma heat measuring device and a ceric sulfate dosimeter to make independent measurements and to search for evidence of saturation at higher intensities in the ceric sulfate dosimeter measurements. The results of the two methods agree within 20% with no apparent saturation.

IDO-16128

Hogg C H
AVERAGE THERMAL NEUTRON FLUX FROM BISMUTH MONITOR,
Atomic Energy Division, Phillips Petroleum Company, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, October 21, 1953, 12 pp. (7 refs).

As a part of the neutron flux measurement program of the Reactor Physics Group at the MTR, a technique of measuring the average thermal neutron flux has been developed which is based on the heat generated by the decay of Po^{210} in irradiated bismuth. The heat generation in the irradiated sample is measured with a rod-type thermistor calorimeter.

An equation for calculating the flux is derived. The average flux in an experimental facility found to be $2.3 \times 10^{14} \pm 20\%$ with the bismuth compares favorably with the value 2.2×10^{14} measured with an indium foil technique.

IDO-16129

Hogg Calvin H
ROUTINE MEASUREMENT OF GAMMA INTENSITY,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, November 2, 1953, 7 pp.

An instrument for measuring the gamma intensity in the MTR gamma facility by means of the heat generated in a rod-type calorimeter is described. The instrument utilizes the temperature difference, produced by gamma heating, between the ends of a solid cylinder insulated so that most of the heat escapes through one end. A calibration curve is included.

IDO-16173

Webster J W
AN ANALYSIS OF THE ACCURACY OF PERTURBATION THEORY,
Atomic Energy Division, Phillips Petroleum Company, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, June 17, 1954, 24 pp. (4 refs).

This report discusses the accuracy of two-group perturbation theory as a method of calculating the effect on reactivity of small changes to the composition of a reactor. The evaluation is based on a comparison of reactivity changes calculated by group theory and perturbation theory for cases involving uniform changes in the core or reflector. The group theory has fewer approximations to apply than perturbation theory. It can only be used for uniform changes whereas the latter can be used for localized and nonuniform changes.

Perturbation theory is compared with standard two-group theory for uniform changes in composition of a proposed MTR Reactivity Measurement Facility. It is concluded that the perturbation theory is accurate within one part in ten for a uniform change in any one constant of 15% or less. Graphs are given of reactivity effect versus arbitrary percentage change in the various constants as calculated by the two methods. The generalized formula of perturbation theory is discussed term by term, and a physical interpretation is shown to exist for each term.

IDO-16213

Heath R L
FISSION PRODUCT MONITORING IN REACTOR COOLANT STEAMS,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, January 1, 1956, 113 pp.

In the operation of high-flux, water-cooled reactors the detection of fission product activity in coolant streams is an important consideration. MTR experience has indicated the limitations of systems normally employed for this purpose. This has led to the development of a new type fission product monitor exhibiting nearly ideal characteristics. This system utilizes continuous isolation of fission product iodine, combining gamma energy discrimination with the use of ion exchange resins. The system responds essentially only to 86 sec I^{136}, 54 min I^{134}, and 6.7 hr I^{135}, utilizing energy discrimination below 800 kev with a simple level discriminator and a NaI detector viewing either the effluent from a cation resin column or the integrated activity on an anion resin. This offers the advantage of unique response to short-lived fission products, thus measuring the instantaneous production rate. The use of iodine activity integrated upon an anion resin column achieves sensitivity orders of magnitude above direct stream observation. Operational experience with this type monitor has indicated negligible response to non-fission product background activity with more than adequate sensitivity for the detection of fission products. A review of the methods which have previously been employed for the detection of fission products is presented with a discussion of their relative merits in comparison with the new iodine system. This includes both gamma detection directly in the water stream using energy discrimination (differential gamma monitor) and the detection of delayed neutron activity. The theory of operation of all these devices will be developed in some detail including a general discussion of the background activity problem in aluminum and stainless reactor cores as related to the problem of fission product detection. In addition information is presented concerning the mechanisms of fission product evolution from different type fuel elements and the operational consequences of fuel cladding failures as gained from MTR experience with actual fuel element failure.

IDO-16243

Preston R J
THE MTR AUTOMATIC WIRE SCANNER,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, September 29, 1955, 44 pp.

The MTR Automatic Wire Scanner is an integrated design and simple to use. For routine work an operator inserts a wire, actuates the drive-start switch, selects his carriage speed, and may then proceed with other work. The wire scanner automatically handles the complete cycle. In brief, the wire is carried to the proper position for scan commencement, wire direction reversed, recorder turned on, wire scanned automatically according to length, carriage reversed, shifted to high speed, and automatically returned to the load point. Manual cycles may be run and manual control may override the automatic cycle at any time regardless of control configuration. Any wire position may be relocated within 0.010 of an inch for rechecking a point. Wire velocity may be varied from 1/4 inch per minute to 5 inches per minute, and panel lamps indicate control configurations at all times. Wire resolution with activities under 500 counts per second is excellent and only slight evidence of end effect may be noted. With higher activities, however, end effect becomes appreciable. For this reason and because of

the health physics problems of handling very hot wires, irradiation times are used which result in activities of the order of 50,000 counts per second per inch of wire. It also happens that these times are sufficiently long that good timing accuracy may be easily achieved.

IDO-16247

Francis W C and Marsden L L
EXPERIMENTAL AND THEORETICAL VALUES OF THE GAMMA DECAY DOSE RATE AND HEATING FROM SPENT MTR FUEL ELEMENTS,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, January 13, 1956, 58 pp.

With the use of spent MTR fuel assemblies as sources of high intensity gamma radiation, not only at the National Reactor Testing Station, but also at various other installations in the USA, a comprehensive study of the decay of these elements was essential. This report contains the results of a joint project at the Materials Testing Reactor to measure and calculate gamma decay dose rate and heating from the spent fuel elements as a function of fission time, cooling time, and distance from source. A comparison of these data is presented. Fuel elements with cooling times from 3-3/4 hours to 218 days after reactor shutdown and burn-ups from 3-1/2 to 35% have been studied. Experimental and theoretical data are generally in good agreement for dose rate measurements, but are not as consistent for heating values.

IDO-16251 MTRL-54-51

Webster J W
METHOD FOR MAKING MEASUREMENTS IN THE RMF,
Atomic Energy Division, Phillips Petroleum Company, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, June 25, 1954, 13 pp.

This report summarizes some preliminary thoughts and calculations on the theoretical aspects of making measurements in the proposed RMF. Attention is given to ways of separating the effects of fuel and poison and to accuracy and sensitivity.

IDO-16252

McMurry H L
PERTURBATION THEORY AND APPLICATIONS - I. THEORETICAL,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, January 11, 1958, 22 pp. (6 refs).

The bases for the two-group perturbation theory for reflected reactors are presented. Working equations for calculating the effects of arbitrary perturbations are derived.

IDO-16408

Heath R L
SCINTILLATION SPECTROMETRY. GAMMA-RAY SPECTRUM CATALOGUE,
Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July 1, 1957, 99 pp.

Gamma scintillation spectrometry as a method of radioactivity measurement has gained wide acceptance in the past few years. It would seem, however, that its general use has been limited severely both in scope and precision by the lack of adequate published information on the characteristics of the detectors. The techniques have been in general use in the research laboratories for several years now, but the information needed to promote their general use has remained largely in unpublished form. In view of possibilities which this method offers in applied radiation measurement studies, for both qualitative and quantitative application, it was felt that an effort should be made to make available the necessary information in a form which can be readily applied in the routine laboratory.

IDO-16440

Metcalf D R and Cazier G A
SPHERICAL HARMONIC METHODS IN SLAB GEOMETRY,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, March 21, 1958, 38 pp. (3 refs).

The P-1 and P-3 spherical harmonic approximations to the Boltzmann transport equation in slab geometry and an IBM-650 machine program are developed to obtain flux plots from cross-section and dimension input data. An application was made to a SPERT III fuel assembly with stainless steel clad plates. In the P-3 approximation at 68°F, the ratio of the average flux in the moderator to the average flux in the fuel plate is 1.05. The conclusion is that for SPERT III fuel assemblies with the spacing that is at present contemplated, it is a fairly good approximation to consider all materials homogeneously distributed in the fuel regions.

IL-0359-1

TINY DETECTOR MAPS NEUTRON FLUX,
Industrial Laboratories, March (1959), 3 pp.

This article discusses a new neutron detector as described in a paper presented before a meeting of the American Nuclear Society by Dr. K. H. Sun. This device is almost completely insensitive to gamma rays. In its simplest form, the miniature detector consists of a tiny slice of silicon or germanium having a sensitive junction or layer near the top surface of the slab. This detector can function as either a fast or slow neutron detector depending on the type surface used.

IU-001-FR/53 AD-17929

Clark G L, Bierstedt P E and Gardner J O
STUDIES OF EFFECTS OF HIGH ENERGY RADIATION,
University of Illinois, Contract No. DA 18-108-CML-2446, 16 pp.

This report constitutes the final summary of investigations under Contract No. DA 18-108-CML-2446. The purpose was to investigate a wide range of possible chemical systems sensitive to high energy radiation from a fundamental and quantitative point of view. Only a few of the numerous systems investigated demonstrated the qualities necessary for a practical field or tactical dosimeter.

JENER-39

Skarsvag K
A FAST NEUTRON DETECTOR,
Joint Establishment for Nuclear Energy Research, Kjeffer, Norway, December (1955), 8 pp. (7 refs).

A fast neutron detector of the Hornyak type with and without light guides is described and the efficiency of the detector discussed.

JENER-Pub-8

Ehrenberg L and Saeland E
CHEMICAL DOSIMETRY OF RADIATIONS GIVING DIFFERENT ION DENSITIES. AN EXPERIMENTAL DETERMINATION OF G VALUES FOR FE^{2+} OXIDATIONS,
Joint Establishment for Nuclear Energy Research, Kjeller per Lillestrom, Norway (1954), 25 pp. (41 refs).

The oxidation of air equilibrated $FeSO_4$ in dilute H_2SO_4 by X-rays and by particle radiations resulting from the interaction of pile neutrons with different elements added to the solution has been examined. The following G values (Fe^{3+}/100 ev) were obtained: ^{235}U fission fragments 3.0 ± 0.9; $^{10}B(n\alpha)^7Li$ 4.0 ± 0.4; $^{14}N(np)^{14}C$ 7 ± 1; $^6Li(n\alpha)T$ 5.4 ± 0.3, from which 6.5 ± 0.7 is calculated for the triton; 175 kv X-rays 17.4 ± 0.8. Since for 160 mev protons G is found equal to (16.5 ± 1) Fe^{3+}/100 ev, it is concluded that G is a function only of the ion density (linear energy transfer), not of other properties of the ionizing particle, and that once this function is known the reaction can be used for the dosimetry of all radiations including fast neutrons. An ion chamber determination of the latter agrees well with the actinometric dose. Since G_{Fe}/G_{Ce} is found to vary within a wide range of ion densities, a simultaneous application of ferrous and ceric sulphate dose meters can be used for an estimation of the average ion density of a poly-energetic radiation.

The G values of the particles emanating from boron and lithium are found independent of the pile position and of the background intensity. Since, further, dG/dT of densely ionizing radiations (represented by fast neutrons) is found to be zero, it is proved that under the actual conditions the effects due to densely and sparsely ionizing radiations applied simultaneously are additive.

Fe^{3+} was determined photometrically at 465 mμ as thiocyanate complex. When 0.7 ml 3N KSCN is added to 3 ml Fe solution, optimum conditions of sensitivity (molar extinction 8500), stability, and temperature dependence are obtained.

JSI-0256

Anderson A R and Waite R J
A CALORIMETER FOR MEASURING ENERGY ABSORPTION FROM PILE RADIATION,
Journal of Scientific Instruments, Vol. 33, No. 2, pp. 46-51, February (1956), (7 refs).

An adiabatic calorimeter has been designed for the measurement of energy absorption from pile radiation. Some of the unusual problems encountered in this type of calorimetry are discussed. The preliminary work leading to a suitable design of calorimeter is summarized and full descriptions of the instrument and measurement techniques

are given. Electrical calibrations of three samples with widely different thermal conductivities have demonstrated the satisfactory behaviour of the calorimeter over a wide range of power inputs. The results of some measurements in the Harwell pile BEPO are briefly discussed.

K-497

Rohr R C, Rohrer E R and Macklin R L
PROPORTIONAL FISSION NEUTRON COUNTERS,
US Atomic Energy Commission, Technical Information Service Extension, Oak Ridge, Tennessee, August 1, 1949, 8 pp. (5 refs).

Some proportional fission neutron counters are described with information on methods of preparation and details of a circuit for a portable model. The portable instrument has an efficiency of .01% for neutrons from polonium beryllium sources.

KAPL-329 (Pt. I)

Stewart H B and Gasein G B
ACTIVATION EXPERIMENTS IN THE KAPL PRELIMINARY PILE ASSEMBLIES,
Part I. Experimental Procedures, Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, September 20, 1950, 53 pp.

In order to obtain a preliminary knowledge of the characteristics of reactors having a neutron spectrum predominantly in the intermediate energy range, a number of experiments have been conducted on several critical assemblies which were designed to have the same general features as the contemplated KAPL reactor. The results of some of the activation experiments which have been conducted on these preliminary pile assemblies will be summarized in three reports as follows:

Part I - Experimental Procedures
Part II - Results of Power Distribution and Neutron Flux Experiments for PPA-2, -3, -4, and -5
Part III - Alpha Experiments in PPA-5

This report, Part I, is limited to a description of the experimental procedures and calibration experiments required for the activation measurements.

KAPL-1045

Fitzgerald J J, Hurwitz H, Jr. and Tanks L
METHOD FOR EVALUATING RADIATION HAZARDS FROM A NUCLEAR INCIDENT,
Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, March 26, 1954, 52 pp. (2 refs).

A method to evaluate the radiation hazards from a nuclear incident is discussed in this report. Several new formulas for the determination of the integrated dose from external and internal radiation and the fall-out of activity from the fission-products cloud are developed in the appendices.

KAPL-1406

Stearns R F
HIGH-LEVEL CONTAMINATION CONTROL AND WASTE DISPOSAL,
Knolls Atomic Power Laboratory, Schenectady, New York, November 1, 1955, 19 pp.

The clean-up and disposal of radioactive waste in the Radioactive Materials Laboratory at the Knolls Atomic Power Laboratory is lessened considerably if the problems of radioactive contamination are taken into consideration during the design of irradiation test devices and laboratory equipment.

Operational experience and engineering work have also resulted in development of many techniques and equipment which have aided in reducing the costs of high-level radioactive clean-up and waste disposal.

KAPL-1469

Zweifel P F and Petrie C D
AVERAGES OF THERMAL CROSS SECTIONS FOR HYDROGEN-MODERATED ASSEMBLIES,
General Electric Company, Knolls Atomic Power Laboratory, Schenectady, New York,
Contract No. W-31-109-Eng-52, January 1, 1956, 34 pp.

Average thermal cross sections are found using the Wigner-Wilkins thermal neutron spectrum assuming moderation by a perfect gas of hydrogen molecules in the presence of a 1/v absorber. Results are given for $\sigma_a U^{235}$, $\sigma_a Xe^{135}$, a 1/v cross section, $\sigma_{tr}H$ and $\lambda_{tr}H$. The diffusion length is calculated for pure water, and methods of calculating diffusion lengths for combinations of other materials with water are indicated. The results of the diffusion length calculations appear to be in reasonable agreement with experiment.

KAPL-1916

Stone R S and Slovacek R E
NEUTRON SPECTRO MEASUREMENTS,
Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52,
September 15, 1957, 30 pp. (11 refs).

Thermal neutron spectra have been measured with time-of-flight techniques. Spectra were obtained for pure water and for a nearly homogeneous subcritical assembly where the ratio of thermal absorption to high energy scattering cross section was 0.3. For each medium, spectra were measured at 298° and 586° K.

The experimental results are presented and compared with calculated theoretical spectra. The agreement between theory and experiment is excellent for the multiplying media. On the basis of this agreement, one concludes that chemical binding effects in light water play a negligible role in determining the equilibrium neutron spectrum in water assemblies.

KAPL-2007

Johnson D W and Romesberg E J
CALCULATION OF FLUX TO DOSE RATE CONVERSION FACTORS FOR FAST AND INTERMEDIATE ENERGY NEUTRONS,
Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, March 20, 1959, 10 pp. (10 refs).

The ideal neutron dosimeter would have a response to neutrons of different energies proportional to the variation of damage to tissue. For such an instrument, the neutron source used for calibration need not have the same spectrum as the flux being measured for dose rate. The conversion factor to be used for a polonium-beryllium source for calibrating such an ideal detector is 0.13 mrem/hr per Po-Be neutron/cm^2-sec.

An instrument which approaches this ideal is the Hurst detector. However, since this detector does not detect neutrons of energy $\lesssim 0.2$ Mev, the "long counter" (paraffin-wrapped BF_3 detector) is often used for detecting in the intermediate energy range (thermal energy $\lesssim E \lesssim 0.2$ Mev). The problems of reading dose rates with these types of instruments are discussed.

KAPL-M-EBF-1

Fehr E B
PREPARATION OF BORON TRIFLUORIDE AND FILLING OF NEUTRON COUNTERS,
Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, February 18, 1955, 20 pp. (9 refs).

The technique used at KAPL for preparation of pure boron trifluoride from the calcium fluoborate is described. This method is used for filling special pulse counting ionization chambers (IC5) which are used for control and experimental measurements in low power nuclear reactors.

KAPL-M-ELW-4

Wachspress E L
NOTES ON A STREAMING PROBLEM,
Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, April 8, 1954, 14 pp.

A method is presented for the calculation of the leakage of neutrons out of the ends of a cylindrical hole of radius "a" and height "H" where the neutron flux along the surface of the hole is a known function of 2 only. For the cases which are of interest the flux is symmetric about the plane, Z = 0. Hence, the flux may be expanded in a Fourier cosine series where each term is of the form $Q_c = \cos \pi z/H_c$.

KAPL-M-SP-4

Pearlstein E and Abrams M J
THE CONVERSION OF FAST NEUTRON FLUX TO DOSE,
Knolls Atomic Power Laboratory, Schenectady, New York, Contract No. W-31-109-Eng-52, June 10, 1954, 10 pp. (4 refs).

The single collision and multicollision dose conversion curves have been applied to the Po-Be and fission neutron spectrums within the limits of 0.1 Mev and infinity to determine an average flux to dose conversion factor. The results are:

	Single Collision Dose		Multicollision Dose	
	neutes / cm^2 sec	mrep / hr	neutes / cm^2 sec	mrep / hr
Po-Be Source	74.0		42.1	
Fission Source	97.6		60.6	

LA-753

Watts Richard J
PORTABLE FAST-NEUTRON FISSION-CHAMBER MONITOR,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, October 13, 1949, 13 pp.

An instrument that will detect fast neutrons by means of the fission of U^{238} is described. To attenuate the slow-neutron effect, the uranium is depleted of the 235 isotope to the ratio 5000/1. Battery-operated feedback amplifiers are used to obtain a pulse height sufficient to operate a discriminator and headphones. Circuit diagrams are given.

LA-1284

Storm Ellery
THE RESPONSE OF SENSITIVE 552 DUPONT FILM TO BETA RADIATION,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, August 31, 1951, 28 pp. (3 refs).

The response to beta radiation of sensitive 552 Dupont film, enclosed in the usual manufacturer's packet, was measured in terms of rep. Seven beta-emitting isotopes covering a maximum energy range from 0.26 to 3.50 Mev were used. The exposures were measured in rep by means of an air ionization extrapolation chamber. The film response was found to diminish sharply below 0.8 Mev, and became nearly energy independent beyond 2.5 Mev. A method for determining both the energy and the exposure of a film exposed to gamma and beta radiation is also described.

LA-1391

Carlson Bengt
MULTI-VELOCITY SERBER-WILSON NEUTRON DIFFUSION CALCULATIONS,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, March 24, 1952, 34 pp. (5 refs).

The calculations of certain types of neutron diffusion are much simplified by the use of the Serber-Wilson method. A derivation is given along with sample calculations incorporating comparisons with the integro-differential method, and with the spherical harmonic method.

LA-1670 X-9613

Frye Glenn M, Jr., Gammel Juanita H and Rosen Louis
ENERGY SPECTRUM OF NEUTRONS FROM THERMAL NEUTRON FISSION OF U^{235} AND FROM AN UNTAMPED MULTIPLYING ASSEMBLY OF U^{235},
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, May (1954), 18 pp.

The neutron fission spectrum of U^{235} has been measured from 0.3 to 12.0 Mev using the method of proton recoils in nuclear emulsions. The resulting neutron spectrum may be represented by the formula $N(E) = 1.058 \cdot 10^3 \, e^{-E/0.965} \sinh \sqrt{2.29E}$. The Godiva leakage spectrum was also measured and shows a higher proportion of low energy neutrons.

LA-1721 (Rev)

Kleinberg J, et al.
COLLECTED RADIOCHEMICAL PROCEDURES,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, December 4, 1954, 287 pp.

This report is a compilation of radiochemical procedures as developed and used in the Los Alamos Scientific Laboratory. Many of these techniques are adaptations of procedures previously reported in the literature and supersedes LA-1566, LA-1721, LA-1722, AECD-3674, and LA-1567. The elements are grouped into three classes: (1) the regular elements, (2) the elements of the short transition series, and (3) the elements of the long transition series.

LA-1835

Barker Robert F
GENERAL HANDBOOK FOR RADIATION MONITORING,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, September (1954), 91 pp.

This handbook was prepared specifically for use at the Los Alamos Scientific Laboratory. The philosophy and procedures set forth apply to the situations and needs found there. Definitions included in the glossary are specific applications of the terms in the realm of radiation monitoring and do not necessarily include the complete definitions as applied to general nuclear energy fields.

LA-1916

Cranberg Lawrence and Nereson Norris G
FISSION NEUTRON SPECTRUM OF U^{235} FROM 0.2 TO 3 MEV,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, May (1955), 42 pp. (19 refs).

The neutron spectrum associated with the fission of U^{235} induced by slow neutrons has been measured from 0.175 to 3.0 Mev. The experiment was carried out by measuring the flight time of the fission neutrons from their U^{235} source to the detector. Emphasis was placed on setting up a clean experimental arrangement and on obtaining a reliable background measurement. Background percentages ranged from 18% at the lowest energy to 2% at the highest energy.

The energy resolution of the measurements varied from about 13% at 0.2 Mev to 40% at 2 Mev; the corresponding statistical errors at these energies were 9 and 3%. Other errors combined with the above values to give an over-all accuracy of approximately ±10% over the low energy region. Within the above error limits, the experimental points confirm the relation, $N(E) = kEe^{-0.775E}$, which is in current use for expressing the fission spectrum.

LA-1938

Young D S
PARAFFIN CYLINDERS TO MEASURE NEUTRON ENERGIES,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, November 28, 1955, 25 pp. (13 refs).

A method is presented of measuring average neutron energies in the range from 19 kev to 4.5 Mev. When the thickness of paraffin around a boron-lined chamber is increased, the counting rate at first increases and then decreases. The thickness at which the highest counting rate occurs is sensitive to the energy of the source neutrons. The optimum thickness of paraffin for an antimony-beryllium photoneutron source whose neutrons have been degraded to a probable average energy of 19 kev is 1.5 inches. The optimum thickness for a polonium-lithium source whose neutrons have a probable average energy of 250 kev is 2.0 inches, and the optimum thickness for a plutonium-beryllium source whose neutrons have a probable average energy of 4.5 Mev is 3.0 inches. From the shape of response as a function of paraffin thickness, it is possible to get an idea of the spread of neutron energies.

LA-1964

Graves Glen A
SOME FOIL ABSORPTION CALCULATIONS,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, February 7, 1956, 38 pp.

Equations for the calculation of transmission and absorption of neutron fluxes in single thin foils and in individual members of a foil sandwich consisting of three foils of the same material placed in intimate contact. The following cases are considered:

1. Foil absorption in a collimated flux of monoergic neutrons.
2. Foil absorption in an isotropic flux of monoergic neutrons.
3. Foil absorption in an isotropic flux of neutrons distributed in energy, including resonance cases.
4. Sandwich absorptions in an isotropic flux of neutrons distributed in energy, including resonance cases.

LA-2152

Glare James Paul
EQUIPMENT FOR EXPERIMENTS WITH ACTIVITIES HAVING HALF-LIVES IN THE RANGE FROM 10 MICROSECONDS TO 1 SECOND,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, September (1957), 31 pp. (3 refs).

The electronic circuits described were built for conducting experiments with radioactivities having half-lives of 10 microsec to 1 sec range. The Model 10 Beam Shim Pulser was designed for pulsing the beam of an electrostatic generator. It produces +550 volt pulses with rise and fall times of 1 microsec and an adjustable pulse length of 10 microsec to 1 sec into a capacitive load of 100 micromicrofarads. The Model 10 10-channel Time Delay Analyzer has channel widths of 10 microsec to 1 sec and was built for determining half-lives of radioactivities in this time range. The Model 1 Delay and Gating Circuit is used with a 100-channel pulse height analyzer to turn it on and off with a 1 microsec accuracy. The Model 2A Gating Unit incorporates delayed coincidence circuits which control the operation of the analyzer.

LA-2174

Sayeg J A and Harris P S
EXPERIMENTAL DETERMINATION OF FAST-AND THERMAL-NEUTRON TISSUE DOSE, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, January (1958), 65 pp.

Beryllium-shelled tissue-equivalent and beryllium-shelled graphite ionization chambers which permit the measurement of fast- and thermal-neutron tissue dose are described. Measurements on fast neutrons (14.1 Mev and degraded fission neutrons) were compared with the Hurst proportional counter and threshold detectors. The data indicate close agreement between the different experimental systems and first-collision theory.

Measurements on thermal neutrons made at Los Alamos Water Boiler with tissue-equivalent nitrogen-depleted and graphite ionization chambers were in agreement with theoretical calculations on: (1) the proton portion of the total thermal-neutron dose due to the N^{14} (n, p) C^{14} reaction in tissue, and (2) the gamma portion of the total thermal-neutron dose due to the $H^{1}(n, \gamma)H^{2}$ reaction in tissue. Also, the inherent gamma contamination as measured with the graphite chamber was in close agreement with the lithium extrapolation measurements of Brennan, et al. The results and errors are discussed in the calculation of neutron tissue dose.

LAC-NR-51 (Vol. 1)-7

Fainman M Z, et al.
A DESCRIPTION OF A MULTI-KILOCURIE IRRADIATION FACILITY AND THE ASSOCIATED RADIATION DOSIMETRY,
Inland Testing Laboratories, Morton Grove, Illinois. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 7 pp. (7 refs).

Inland Testing Laboratories has designed, constructed, and is operating a large multi-kilocurie cobalt 60 irradiation facility. The cobalt 60 source at this facility is approximately 50,000 curies and produces a dose rate of 10^{6} roentgens per hour.

The design of the source configuration and the large cave facility makes possible the testing, both static and dynamic, of a large variety of materials within a high radiation flux environment. This facility also provides sufficient space to perform many tests simultaneously at relatively uniform high dose rates.

Specifically, this paper is concerned with the developmental research regarding the design of the source configuration, the albedo characteristics of the cave, the assay and total activity of the source as measured by graphite ionization chamber, and the assembly and isodose plot of the completed source.

LAC-NR-51 (Vol. 1)-9

Lide E N
REMOTE AREA MONITORING SYSTEM AT AIR FORCE PLANT NO. 67,
Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 3 pp.

To conform to Air Force Plant No. 67 facility requirements for the capability of rapidly irradiating large numbers of test articles, including aircraft subsystems in operation, the Radiation Effects Reactor operates above ground with essentially no shielding. This condition necessitates the monitoring of neutron and gamma flux levels at selected stations of the site and at the perimeter during reactor operation. A remotely operated radiological monitor system has been developed for this purpose.

The functions of this system are as follows:

1. Supply primary power to the remote detectors and instrumentation,
2. Sequentially select the type of radiation to be monitored,
3. Provide a means of conducting the radiation analog currents back to the central station for recording and for identifying the radiation type and originating station.

To accomplish these functions some special concepts for power transmission and for signal selection and transmission have been developed. Individual detectors and special circuitry for the system are described in companion papers following:

1. LAC-NR-51 (Vol. 1)-10 -- R. L. Shipp, Area Monitoring for Radioactivity
2. LAC-NR-51 (Vol. 1)-11 -- L. A. Turner, Logarithmic Circuits for Radiation Dosimetry

LAC-NR-51 (Vol. 1)-10

Shipp Roy L
AREA MONITORING FOR RADIOACTIVITY,
Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 3 pp.

The radiation effects reactor is designed to provide sufficient gamma and neutron leakage flux to irradiate large aircraft subsystems and components. This design requirement necessitates operation of the reactor above ground with a minimum amount of shielding, with the result that above-tolerance fluxes extend beyond the bounds of the reactor building. The predicted gamma flux, for instance, is one roentgen per hour at the 3600-foot radius exclusion fence.

To ensure the safety of people in the general vicinity of the site, monitor stations are situated around the exclusion fence to provide readings for use in controlling radiological hazards. Figure 1 is an area map showing the layout of the area monitoring system. Also, additional stations are located at the peripheral fence to measure radiological hazards at the site boundary. The radiological factors monitored at the station include concentration of argon-41, as well as intensities of fast neutron and gamma radiation. Data from the remote monitor stations are transmitted to central recording and alarm stations. Data primarily concerned with hazards associated with the operation of the Radiation Effects Laboratory and the Critical Experiment Reactor are transmitted to the Nuclear Support Laboratory.

The development of the area monitoring system was a result of the coordinated effort of three groups. Coverage in this paper, however, is restricted to the development of detectors and certain aspects of the argon-41 problem peculiar to this facility.

Design considerations for the entire system were remote operation, reliability, no protection from weather, and minimum power utilization.

LAC-NR-51 (Vol. 1)-11

Turner L A
LOGARITHMIC CIRCUITS FOR RADIATION DOSIMETRY,
Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 3 pp.

At Air Force Plant No. 67, simple circuits are available for the logarithmic measurement of a-c and d-c voltages and frequencies or pulse repetition rates. Ranges of over 100 db are easily obtained.

LAC-NR-51 (Vol. 2)-12

Maienschein F C
INFLUENCE OF ENERGY SPECTRA ON RADIATION EFFECTS,
Oak Ridge National Laboratory, Oak Ridge, Tennessee. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 31 pp. (62 refs).

The energy spectra of neutrons and gamma rays influence in an important way the production of displacements in crystal lattices. A lack of knowledge of the energy distributions in many past and current reactor irradiations for radiation "effect" studies has led to the accumulation of relatively meaningless data. Special problems arise in attempting to compare data taken at different types of reactors with unknown energy spectra. The available data for reactor spectra are listed and examples given. Methods of spectroscopy are considered briefly which may be useful for developing further spectral data. Finally, the merits are examined of several possible characterizations of a radiation field which are simpler to obtain than the energy spectrum. Comparison of these parameters with those commonly used now shows that the new parameters will constitute a marked improvement in understanding and correlating radiation effects.

LAC-NR-51 (Vol. 2)-13

Burrus Walter R and Sullivan Russell P
AVERAGE NEUTRON CROSS SECTIONS FOR TYPICAL REACTOR SPECTRA,
Ohio State University, Columbus, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 16 pp. (8 refs).

Average neutron cross sections are calculated for 15 common elements. Elastic scattering, inelastic scattering, and charged particle reactions are considered. From these average cross sections, one may calculate a dose in one material from a measured dose in another or one may calculate a dose from an activation, an activation from a dose, or an activation from an activation. The spectra used for calculating the

averages are for fission neutrons which have penetrated various thickness of water and graphite (calculated by NDA by use of the "moments method"). The relationship of the calculated averages to other types of averages is discussed and conversion factors are given. Cross-section averages are also given for several fission foils. Finally, the fraction of the absorbed dose which is transferred to recoil nuclei which does not result in ionization is calculated for five elements. This fraction is useful in comparing radiation effects which are caused by atomic displacements.

LAC-NR-51 (Vol. 2)-14

Caswell R S and Smith S W
NUCLEAR RADIATION UNITS AND MEASUREMENTS,
National Bureau of Standards, Washington, D. C. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 17 pp. (24 refs).

The basic principles underlying the establishment and use of units, standards and systems of measurement for nuclear radiation are given, with specific reference to gamma rays, neutrons and mixed fields of gamma rays and neutrons, the latter being more commonly encountered in radiation effects problems. The measurement of the energy deposited by a radiation field in a sample of material may be approached through measurement of some characteristic of the field, i.e., exposure dose, flux, spectra, or through measurement of energy absorption directly , i.e., absorbed dose. The discussion includes the conditions for measurement of exposure dose and of absorbed dose, and current methods of dosimetry, instruments and techniques. Also included is a brief discussion of the measurement of neutron flux and neutron spectra.

LAC-NR-51 (Vol. 2)-15

Burrus W R and Harper W T
COMPARISON OF RADIATION EFFECTS IN DIFFERENT FACILITIES,
Ohio State University, Columbus, Ohio, and Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 22 pp. (6 refs).

Regardless of any agreement reached on units and methods of measurement within the Nuclear Propelled Manned Aircraft Program, there still exists the problem of correlating the radiation-effects data reported by investigators in agencies that are not participating in the Program. To cope with this problem, a simplified method for consistent comparison of the data obtained in different facilities is presented. This is accomplished by expressing radiation environments in terms of "carbon-absorbed gamma dose" and "water-absorbed neutron dose." Although the method involves some simplifying assumptions and approximations, it is shown to be generally applicable to organic materials, which cause some of the most critical problems for the designer of nuclear-propelled aircraft. The sample calculations, tables, and curves presented may be used as a handbook for conversion of radiation dose data to common denominators. Such conversions permit comparison of data even when information on the spectral distribution of the radiation environment is lacking.

LAC-NR-51 (Vol. 2)-16 FZM-1154

Wheeler G A
THE DETERMINATION OF NUCLEAR PARAMETERS FOR EXPERIMENTAL RADIATION EFFECTS,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 8 pp. (4 refs).

Necessity for knowledge of radiation field is discussed. Current dosimetry techniques in use at Convair are presented together with the differences between present "state-of-the-art" and desired measurements. The magnitude of and difficulties encountered in Convair's mapping of the GTR field are detailed.

LAC-NR-51 (Vol. 2)-17

Gamble Roger L
CALORIMETRIC DOSIMETRY PROGRAM AT LOCKHEED,
Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 6 pp.

To measure energy deposition in organic materials, low cost calorimetric radmeters of both the adiabatic and steady-state types have been designed. The ranges of these instruments are from 5×10^4 rads per hour to 10^7 rads per hour.

LAC-NR-51 (Vol. 2)-18

Schupp F D and Ruby S L
DOSIMETRY AND ENERGY DISTRIBUTION OF FAST NEUTRON USING Li^6I,
Westinghouse Electric Corporation, East Pittsburgh, Pa. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 1 p.

The use of Li^6I(Eu activated) scientillation crystals for neutron spectroscopy in the energy range above 1 Mev has been investigated. The scintillation spectrometer has moderate resolution, high efficiency, and is usable in an isotropic flux; it presents the absolute number of neutrons as well as spectral distribution. A technique of subtracting gamma-ray background by use of a matched Li^7I(Eu) crystal is given. Pulse height spectra with monoenergetic neutrons from 1.6 to 18 Mev are reported. A preliminary study of the energy spectrum of the fast neutron distribution obtained from a partially unshielded pressurized water-type reactor core will be presented.

LAC-NR-51 (Vol. 2)-19

Weiss M M and Donnelly M M
NEUTRON FLUX ENERGY DISTRIBUTION OF THE BNL REACTOR SHIELDING FACILITY,
Bell Telephone Laboratories, Inc., Whippany, N. J. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 14 pp. (6 refs).

A study has been made to determine the neutron flux energy distribution of the BNL reactor shielding facility employed in the semiconductor radiation damage studies by Bell Telephone Laboratories. This facility offers an opportunity for a critical

comparison between the mathematical methods available to compute the fast flux and the experimental methods using foil activation techniques. The methods and equipment used and the results obtained are described. The major effort of flux distribution measurement was in the energy range from 0.1 to 10 Mev.

LAC-NR-51 (Vol. 3)-32

Schmitt R A and Sharp R A
MEASUREMENT OF THE RANGE OF RECOIL ATOMS,
General Atomic, Division of General Dynamics Corporation, San Diego, California. Paper presented at the 3rd Semi-Annual Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 9 pp. (18 refs).

This paper discusses the measurement of the range of recoil atoms. An important problem in the interpretation of radiation-damage and sputtering phenomena is the evaluation of the range of an atom which moves through a lattice after having received an initial energy of 10 to 100 kev. It is also pointed out that a theoretical evaluation of the collision cross section is difficult.

LAMS-2100

Cowan Clyde L, Jr. and Reines Frederick
THE LARGE LIQUID SCINTILLATION DETECTOR AS A NEUTRON SPECTROMETER,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, April 2, 1957, 5 pp.

This report discusses the use of large liquid scintillation detectors which in many geometries allows nearly 100% efficiencies for neutron detection. The high sensitivity of these detectors to gamma rays is discussed.

The procedure uses cadmium (as cadmium octoate) for which the capture-time curves are characteristic and well known. A burst of monochromatic neutrons is allowed to fall on a large liquid scintillator. Measurement of the amplitude of the first pulse would yield NE_n, and a simple count of ensuing neutron capture pulses, properly corrected for efficiencies, would determine N. If scope presentation and Land camera are used, this analysis should require a few minutes.

In measurements of continuous neutron spectra for neutrons below a few Mev energy, the effect of nonlinearity is small and the sum-pulse amplitudes for single neutrons would yield uncertainties of only about 10%. This uncertainty increases with neutron energy and would rise to perhaps as much as 30% at 14 Mev.

LAMS-2154

Arakengy Alfred and Kloepper R M
LIQUID-SCINTILLATOR AND REFLECTIVE-COATING STUDY,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, September (1957), 11 pp.

This report is a study of the comparative responses of some scintillators in tanks of various reflective coatings to gamma rays from Cs^{137} and Co^{60} sources. In order of decreasing quality, the scintillators tested, all of which contained p-terphenyl, were

toluene-POPOP, xylene-α-NPO, polystyrene-α-NPO, and triethylbenzene-POPOP. The reflective coatings tested were: Plasite, α-alumina in sodium silicate, and titanium dioxide in Zapon Aquinate Lacquer.

LA-2174

Sayeg J A and Harris P S
EXPERIMENTAL DETERMINATION OF FAST- AND THERMAL-NEUTRON TISSUE DOSE,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, January (1958), 65 pp.

Beryllium-shelled tissue-equivalent and beryllium-shelled graphite ionization chambers which permit the measurement of fast- and thermal-neutron tissue dose are described. Measurements on fast neutrons (14.1 Mev and degraded fission neutrons) were compared with the Hurst proportional counter and threshold detectors. The data indicate close agreement between the different experimental systems and first-collision theory.

Measurements on thermal neutrons made at Los Alamos Water Boiler with tissue-equivalent, tissue-equivalent nitrogen-depleted, and graphite ionization chambers were in agreement with theoretical calculations on: (1) the proton portion of the total thermal-neutron dose due to the N^{14} (n, p) C^{14} reaction in tissue, and (2) the gamma portion of the total thermal-neutron dose due to the $H^{1}(n,\gamma)H^{2}$ reaction in tissue. Also, the inherent gamma contamination as measured with the graphite chamber was in close agreement with the lithium extrapolation measurements of Brennan, et al. The results and errors are discussed in the calculation of neutron tissue dose.

LAMS-2215

Keepin G R
PULSED NEUTRON TECHNIQUES,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, March (1958), 25 pp. (11 refs).

This report presents a brief survey of pulsed-neutron capabilities for reactor research and development.

Using pulsed-neutron techniques one can measure neutron spectra, flux densities, the basic diffusion constants, capture and scattering cross sections, neutron lifetimes, neutron age, and reactivity. As a case in point, practical application of these techniques to the Los Alamos Scientific Laboratory nuclear-propulsion reactor development program is outlined. The various types of measurements are discussed and compared with reference to pulsed-source requirements and electronics instrumentation limitations. This study has indicated three main types of source which should be considered for a general pulsed neutron program. These are: (1) electron linear accelerators, (2) positive ion accelerators (Cockcroft-Walton type), and (3) pulsed neutron generators. From each of these types, specific units may be selected which meet the requirements of mobility and versatility in a remote-control critical assemblies laboratory. A brief evaluation of each type of source is given, including pertinent performance specifications and representative cost figures.

M-1772

Dessauer Gerhard, Davis Kenneth E and White Fred A
A RADIATION DOSE INTEGRATOR OF HIGH SENSITIVITY,
Contract No. W-7401-Eng-49, September 13, 1945, 8 pp.

This report describes the design and construction of a radiation dose integrator to serve as a radiation monitoring unit of high sensitivity and wide application. It is self-resetting and more sensitive than previous models. The unit can be calibrated to measure neutron and gamma radiation in the range from tolerance dose (at tolerance rate) to large doses (fluxes of hundreds of r units per hour). The integrator is a-c operated and self-recording.

M-3685

Cheka J S
NEUTRON MONITORING BY MEANS OF SPECIAL FINE GRAIN ALPHA EMULSION FILM,
USAEC Technical Information Service Extension, Oak Ridge, Tenn., 16 pp. (4 refs).

This report discusses the use of fine grain alpha emulsion film to monitor personnel for neutron exposure. Calibrations were made to determine the sensitivity of the emulsion for both thermal and fast neutrons in terms of proton tracks observable under a microscope of 970x magnification.

Alpha particle sensitive film has been used at Clinton Laboratories since October 1944, to monitor personnel for neutron exposure. This film is now in the regular film badge in addition to the beta- and gamma-ray sensitive film.

MDDC-360 LADC-135

Taschek R F
RADIOACTIVE THRESHOLD DETECTORS FOR NEUTRONS,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, 15 pp. (9 refs).

Of nine (n, p) and (n, a) reactions studied, only $Be^{9}(n, a)He^{6}$, $p^{31}(n, p)Si^{31}$, and $S^{32}(n, p)p^{32}$ gave measurable activities of the residual nucleus after bombardment by neutrons below 2 Mev, and of these three only p^{31} had the combination of cross section and half-life to make a very practical threshold detector for neutrons. The 4.1 hour noncapture excitation of In was investigated as a function of neutron energy. The threshold and variation of cross section with energy of the $p^{31}(n, p)Si^{31}$ reactions were measured in detail.

MDDC-1025

Wilson H A
BODY TISSUE IONIZATION DUE TO NEUTRONS,
United States Atomic Energy Commission, Oak Ridge, Tenn., July 26, 1943, 8 pp. (1 ref).

This report developes a calculation of the body tissue ionization due to neutrons. Most of the ionization is due to the gamma rays emitted when the neutrons are captured. The assumption that all the neutrons falling on the tissue enter the tissue is, of course, not correct. The fraction entering is probably about 0.3 for thermal neutrons and larger for fast neutrons.

MDDC-1180

Bell P R
POCKET RADIATION ALARM,
Clinton National Laboratory (1947), 9 pp.

This report describes a pocket radiation alarm. The weight of the completed instrument is 386 grams and measures 1-3/8 x 2-1/4 x 5-3/4 inches. The sensitivity is adjusted by varying the thickness of a graphite-coated lucite block, in the counter wall, until the capacity of the chamber has the desired value.

Mon P-219

Dismuke Nancy M and Arnette Ruth M
AGE TO THERMAL ENERGY (0.025 EV) OF FISSION NEUTRONS IN H_2O-Al MIXTURES,
USAEC Technical Information Service Extension, Oak Ridge, Tenn., December 5, 1946, 6 pp.

This report discusses the calculation of neutron age in a H_2O-Al mixture as a function of energy. The formula used is presented. Two curves and one table of data are included.

N-0358-1

Kaufmann Stefan G and Pahis Leroy E
NEUTRON DETECTORS FOR OPERATION AT 400C,
Nucleonics, Vol. 16, No. 3, pp. 90, 92, 93, March (1958).

This paper describes a neutron detector designed for operation at 400°C. This device was developed to satisfy the contemplated instrumentation needs for the second Experimental Breeder Reactor (EBR-II).

N-0753-1

Rosen Louis
NUCLEAR EMULSION TECHNIQUES FOR THE MEASUREMENT OF NEUTRON ENERGY SPECTRA - PART I,
Nucleonics, Vol. 11, No. 7, pp. 32-38, July (1953), (80 refs).

In a detailed review, measurement procedures for extended neutron sources are presented, together with an introduction to the discussion of point sources. A preliminary discussion gives specific emulsion processing techniques and evaluates available optical equipment.

N-0853-1

Rosen Louis
NUCLEAR EMULSION TECHNIQUES FOR THE MEASUREMENT OF NEUTRON ENERGY SPECTRA - PART II,
Nucleonics, Vol. 11, No. 8, pp. 38-43, August (1953), (5 refs).

A nuclear plate used as radiator and detector allows measurement of low energy and low intensity neutron point sources. Applications of the emulsion technique to high energy sources and inelastic neutron interactions are described in detail.

N-1058-1

Jensen Gert, et al.
SLOW, SIMPLE 99 - CHANNEL PULSE - HEIGHT ANALYZER,
Nucleonics, Vol. 16, No. 10, pp. 101-103, October (1958).

The paper describes briefly a slow, comparatively simple 99-channel pulse-height analyzer. Since the analyzer was intended for low-level-activity radiobiological work, long-term stability was emphasized rather than speed.

N-1058-2

Moody J W, et al.
PHOTOVOLTAIC GAMMA-RAY DOSIMETER,
Nucleonics, Vol. 16, No. 10, pp. 101-103, October (1958), (4 refs).

Both photoconductive and photovoltaic devices are now being used to detect and measure light intensities or to convert solar energy into electrical energy. Such devices depend upon the excitation of electric charge carriers by radiant energy and, within certain limits, their response is proportional to the intensity of incident energy. The energizing radiation need not be visible; photosensitive semiconductors are also sensitive to gamma-rays, X-rays, protons, and neutrons, and they can be used to detect and measure such radiations.

The particular photovoltaic cell studied in this case was a commercially available silicon solar cell.

N-1158-1

Downs John W and Smith Forrest L
ORGANIC-GLASS SCINTILLATORS,
Nucleonics, Vol. 16, No. 3, pp. 94-96, November (1958).

As a contribution to the development of new scintillators, a study has been made of two organic silane compounds: triphenyl-p-biphenylylsilane and phenyltri-p-biphenylylsilane. These compounds are of interest because they are natural glass formers as well as good scintillators.

This report discusses physical properties, preparation of specimens, method of evaluation, relative efficiency, method of evaluation, and spectral characteristics.

NAA-SR-38

Mills M M
THEORY OF ATOMIC DISPLACEMENTS PRODUCED BY FAST ELECTRONS,
North American Aviation, Inc., Los Angeles, California, Contract No. AT-(11-1)-Gen-8, January 20, 1950, 46 pp. (21 refs).

Theoretical computations are given describing the production fo atomic displacements in graphite by fast electrons. The underlying mechanism is assumed to be the elastic transfer of energy from the electron to a struck carbon atom as a whole when the electron encounters the coulomb field of the carbon nucleus. The agreement between recent experimental electron bombardment data and the theory proposed here is good enough to indicate that the proposed mechanism is probably correct, and that intense ionization does not lead to atomic displacement effects in graphite. The low mass of the electron makes electron bombardment a sensitive technique to supplement irradiation studies of materials carried out by other methods; for example, electron bombardment offers a suitable method to determine the energy necessary to displace an atom from its normal lattice site. Radiation damage in reactors, produced by electrons, is negligible in comparison to damage produced by fast neutrons; however, it is possible for fast electrons to produce radiation damage.

NAA-SR-1076

Martin David H
CORRECTION FACTORS FOR MEASUREMENTS WITH CADMIUM COVERED FOILS,
Nuclear Engineering and Manufacturing, Division of North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, October 15, 1954, 13 pp. (5 refs).

Cadmium-covered foils are frequently used to measure the neutron flux with energy above that represented by the cadmium cutoff point. Correction factors to account for the attenuation of the epicadmium neutrons by the cadmium are given and compared with results by earlier experimenters. In the present work, foil area, foil thickness, and cadmium ratio were varied with no detectible effect on the correction factor. Values are given for both indium and gold, and a further small correction to account for the leak-through of subcadmium or thermal neutrons is discussed.

NAA-SR-1459

Brinkman J A
THE PRODUCTION OF ATOMIC DISPLACEMENTS BY HIGH ENERGY PARTICLES,
Nuclear Engineering and Manufacturing, Division of North American Aviation, Inc., Downey, California, Contract No. AT-(11-1)-Gen-8, October 5, 1955, 52 pp. (39 refs).

The processes by which atoms in solids are displaced from their normal positions by high energy neutrons, cyclotron particles and electrons are discussed. A radiation damage model is presented which involves two basic features: (1) the production of interstitial atoms and vacant lattice sites, and (2) the production of displacement spikes. These two concepts are sufficient to account for most of the observed property changes resulting from atomic displacement by high energy particles. Some of the experimental results which provide the most direct support for these concepts are presented.

NAA-SR-1536

Hart R S and Hale J P, Jr.
FAST NEUTRON MONITORING WITH NTA FILM PACKETS,
Atomics International, Division of North American Aviation, Inc., Canoga Park, California, Contract No. AT-(11-1)-Gen-8, July 15, 1956, 22 pp. (6 refs).

An investigation into the value of dental size NTA film packets for fast-neutron monitoring largely substantiated the results of previous work. Its accuracy, especially at or below tolerance levels, is poor. Nevertheless, in lieu of better techniques, it offers a moderately convenient method that can be easily worked into the usual beta-gamma personnel film system.

A two-week tolerance dose of fast neutrons was represented by $\sim 3.7 \pm 1.0 \times 10^3$ proton recoil tracks per cm^2. At 970x magnification, this results in ~0.66 tracks per field. Cadmium shields were used to restrict the film response to proton recoils. Latent image fading was found to be relatively unimportant, and the proton tracks could be evaluated without serious interference with a superimposed gamma exposure up to ~ 5 r.

The film was calibrated using a 10 curie Po-Be neutron source in several film orientation patterns. Development processes were standardized with Kodak Liquid X-ray Developer and Fix.

NARF-55-12T

Secrest E L
SOLID ANGLE CALCULATIONS,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(038)-21117, April 28, 1955, 32 pp. (5 refs).

This report treats in a systematic fashion sphere and disc geometry solid angle calculations. Rigorous expressions are developed for the solid angle subtended by a sphere at a point and by a disc at a point. Approximate expressions are also developed in such a way as to demonstrate the range of their applicability.

NARF-55-19T MR-N-80

Woodruff L V and Hessee E W
AIR AND GROUND SCATTERING OF GAMMA RAYS AND NEUTRONS FROM THE GTR,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(038)-21117, April 28, 1955, 60 pp. (4 refs).

The purpose of this experiment was to obtain measurements of fast neutron and gamma dose rates due to air and ground-scattered reactor radiations. For this test, the Ground Test Reactor was centered in a small water-filled aluminum cylinder of elliptical cross section to provide a nearly isotropic radiation source.

Both total and scattered (air and ground) dose rate measurements were made for reactor-detector separation distances from 30 to 100 feet for elevations ranging from 12.5 to 71.3 feet. The scattered measurements were made by shielding dosimeters from the reactor direct beam; a variation of scattered dose rate with direct beam shield angle was determined.

Results of the total dose rate measurements verify previous preliminary studies; the dose rates for both neutrons and gammas vary roughly as the inverse square of the distance.

The functional dependence of the scattered dose rate on separation distance a changes with height above the ground. At the larger separation distances, for scattered gamma radiation, the dose rate is proportional to $1/a^{1.4}$ and $1/a^{1.2}$ at 12.5 and 71.3 feet above

the ground; the scattered fast neutron dose rate varies as approximately $1/a^{1.5}$ and $1/a$ at the 12.5 and 71.3 foot heights.

NARF-55-55T (Part 1) FZK-9-089

Craver K B, et al.
ACTIVATION HANDBOOK FOR AIRCRAFT DESIGNERS-VOL. 1, PART 1,
Nuclear Physics Group, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, July 1, 1955, 377 pp. (9 refs).

The present interest within the Aircraft Nuclear Propulsion Program in the activation of materials by nuclear radiation has provided an impetus for the preparation of tables which will allow aircraft design engineers to perform activation computations readily. This Activation Handbook is designed to provide the total activation per unit flux per unit weight of various aircraft materials as a function of two parameters: time of irradiation and decay time.

This edition of the handbook contains the thermal neutron gamma activation tables for 89 aircraft alloys. Future volumes of this handbook are contemplated containing additional alloy-activation calculations for nuclear reactions other than the (n, y) type. Revision pages will be supplied as new experimental cross-section data become available.

NARF-55-55T (Part 2) FZK-9-089

Craver K B, et al.
ACTIVATION HANDBOOK FOR AIRCRAFT DESIGNERS--VOL. 1, PART 2,
Nuclear Physics Group, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, July 1, 1955, 329 pp. (9 refs).

The present interest within the Aircraft Nuclear Propulsion Program in the activation of materials by nuclear radiation has provided an impetus for the preparation of tables which will allow aircraft design engineers to perform activation computations readily. This Activation Handbook is designed to provide the total activation per unit flux per unit weight of various aircraft materials as a function of two parameters: time of irradiation and decay time.

This edition of the handbook contains the thermal neutron gamma activation tables for 80 aircraft alloys. Future volumes of this handbook are contemplated containing additional alloy-activation calculations for nuclear reactions other than the (n, y) type. Revision pages will be supplied as new experimental cross-section data become available.

NARF-55-68T MR-N-101

Cook C F, Lang T P and Wheeler D M
DEGRADED RADIATION FROM A LARGE CO^{60} SOURCE,
Nuclear Test Laboratory, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(038)-21117, October 28, 1955, 20 pp. (5 refs).

A two-crystal Compton spectrometer has been used to measure the degraded gamma radiation from the large Co^{60} source. The degraded radiation is attributed to internal source scattering and scattering due to the air column between source and detector.

The total intensity of the degraded radiation in the range from 0.3 to 1 Mev is no more than 22% of the combined intensity of 1.17- and 1.33-Mev gamma rays. The source intensity was measured August 18, 1955, and found to be 19.9 curies.

NARF-56-17T MR-N-126

Lewis J H and King A D
MEASUREMENTS OF DOSE RATES FROM ACTIVATED AIRCRAFT MATERIALS - PART III, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, July 6, 1956, 67 pp. (3 refs).

Thirty-four alloys of steel, nickel, and other metals were activated by neutrons from the Ground Test Reactor during October 1955. This report presents the gamma dose rate data obtained from this experiment.

Measurements were made on material specimens of a standard size. The specimens were transported to and from the reactor by a pneumatic system. Two samples of each material were irradiated, one unshielded and one shielded by 3/16-inch of boron carbide. Measurements were taken with anthracene crystal scintillation dosimeters calibrated against a Co^{60} standard. Data are presented in terms of the dose rate in mr/hr-gm-kw at one foot from a sample of material irradiated for 30 minutes.

Numerous curves are included.

NARF-56-36T MR-N-131

King A D, Lewis J H and Miles T K
MEASUREMENT OF DOSE RATES FROM ACTIVATED AIRCRAFT MATERIAL - PART IV, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, October 31, 1956, 107 pp. (4 refs).

Thirty-seven alloys of steel, nickel, magnesium, aluminum, titanium, cobalt, tungsten carbide, and other metals were activated by neutrons from the Ground Test Reactor during April 1956. This report presents the gamma dose rate data obtained from this experiment.

The specimens were of a standard size, with the exception of the few noted in the data. Some of the samples were irradiated in powdered form and counted in the standard geometry. The specimens were transported to and from the reactor by a pneumatic system. Two samples of each material were irradiated, one unshielded and one shielded by 3/16-inch of boron carbide. Ten of the alloys were irradiated also in a boral carrier, shielded by 1/4-inch of boral. Measurements were taken with anthracene crystal scintillation dosimeters calibrated against a cobalt-60 standard. Data are presented in terms of the dose rate in mr/hr-gm-kw at one foot from a sample of material irradiated for 30 minutes.

Also included is a brief analysis of the alloy data showing, in some cases, a correlation between level of activity and alloy composition. The boron carbide packed carrier is shown to be equivalent to boral as shielding material within a factor of two.

NARF-57-19T (Vol. 4)-10 X-21783

Rogosa G L
THE FUNCTION OF THE NUCLEAR CROSS-SECTION ADVISORY GROUP AND THE REACTOR PHYSICS PLANNING GROUP,
Division of Reactor Development, USAEC, Washington, D.C. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 4 pp.

The functions and method of operation of the Nuclear Cross-Section Advisory Group and the Reactor Physics Planning Group are discussed. Procedures whereby necessary nuclear data may be obtained are given.

NARF-57-19T (Vol. 4)-11 X-21783

Beever E R
GROUND HANDLING STUDY ON GE-ANP GEAR BOX IRRADIATED BY SPT NO. 2,
General Electric Co., ANPD, Cincinnati, Ohio. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 19 pp. (2 refs).

This report describes the body radiation dose and its distribution received while working in a multiple source radiation field.

The radiation field in and around a radioactive jet engine systems panel was thoroughly investigated. Doses received at various parts of the body were measured for two men working in the radiation field.

It was found that the dose received was not uniformly distributed over the body. In fact, the least dose could be accumulated in the most unlikely location; for example, the hands, which are in closest contact with the radioactive system, may actually not accumulate as large a dose as a shoulder or forearm because of the shielding effects of various lesser radioactive components worked upon.

It was concluded that dose could be predicted to some extent when the radiation field is well known, and the total dose could be materially reduced by the use of simple selective shielding of particularly active sources. An ordered work procedure could take maximum advantage of the shielding effects of the equipment worked upon.

In addition, the value of careful selection of material to be incorporated in systems susceptible to irradiation was sharply emphasized when the most active source in the radiation field was identified.

NARF-57-28T MR-N-169

Fink W L
METHODS AND PROCEDURES FOR RADIATION DAMAGE ANALYSIS,
Convair, Fort Worth, Texas, Contract No. AF33(600)-32054, June 27, 1957, 103 pp. (13 refs).

The advent of nuclear power has introduced a new requirement for materials in a radiation field. Methods are presented in this report for normalizing the flux measurements from different reactor facilities to a common unit. The unit selected is energy absorption in the test specimen. This requires a microscopic determination of energy loss by gamma rays and neutrons.

The determination of functional damage thresholds for material application is discussed. These thresholds are based on the energy absorbed by the material. Experimental data are used to relate the change of physical properties under an irradiation environment. A statistical method is presented to aid in the analysis of experimental data.

The "weakest link" concept (i.e., failure occurs when the weakest component fails) is introduced to aid in defining problem areas, and to serve as a fairly good "first approximation" to the lifetimes for operating systems.

A critical review of the methods is presented to review the assumption employed.

NARF-57-57T MR-N-177

Dungan W E
NEUTRON SPECTRUM MEASUREMENTS WITH RADIOACTIVANTS,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, December 30, 1957, 83 pp. (16 refs).

This report describes the experimental methods and results of neutron spectrum measurements with radioactivants in the pneumatic tube of NARF - Ground Test Reactor for a wet-pool configuration. Measurements were made with foils and solution detectors. The results indicate that a three-group (Maxwellian, 1/E, and fast) specification of the neutron flux is sufficient for the GTR. Also given in this report is a semiempirical method for estimation of the total thermal flux, total epithermal flux, and neutron energy distribution for configurations in which a boral shielding material is used.

NARF-58-53T MR-N-220

Summers T W
TWO-REGION NEUTRON TRANSPORT EQUATION,
Convair, Fort Worth, Texas, Contract No. AF33(600)-32054, December 29, 1958, 24 pp. (4 refs).

The two-region neutron transport equation with plane symmetry has been solved by the Wiener-Hopf method for the case in which one region contains a plane, isotropic source parallel to the interface. The results are subject to the restrictions of isotropic scattering without loss of energy and a constant total mean free path. Analytical results are presented for the total flux and the angular flux at the interface. Numerical results for the total flux at the interface are presented in the form of a parameter study.

NAVDOCKS-TP-PL-13

Jelley J F (Chief, Bureau of Yards and Docks)
RADIOLOGICAL RECOVERY OF FIXED MILITARY INSTALLATIONS,
US Naval Radiological Defense Laboratory, San Francisco 24, California, August (1953), 99 pp.

The problem of defense against the contaminating effects of atomic and radiological warfare weapons has necessitated the development of countermeasures to minimize these effects and permit the recovery of fixed installations at the earliest possible time after attack.

It is the purpose of this publication to delineate the problems that engineers must face when fixed installations become contaminated by atomic or radiological warfare; to provide a planning technique that forms an adequate basis for decisions regarding pre-attack preparation or postattack recovery; and to present a summary of the methods and operating procedures to be followed in accomplishing both protection and recovery.

The report includes decontamination procedures, waste disposal, and radiological safety information.

NAVORD-2666 AD-19207

Hirschfield J J, O'Conner D T and Polansky D
GAMMA RAY SOURCES AND TECHNIQUES FOR GAMMA RAY RADIOGRAPHY,
US Naval Ordnance Laboratory, White Oak, Maryland, February 26, 1953, 87 pp.

A general review of radioisotopes used as radiation sources for industrial radiography is given along with production methods, measurement units, standards and nomenclature commonly associated with their use. The specific characteristics of commercially available radiation sources are discussed as well as elements expected to be available in the near future. Particular attention has been paid to the characteristics of various isotopes which determine their suitability for specific types of radiographic inspection. Complete information for the purpose of obtaining optimum radiographs for various object thicknesses and materials is provided. Information is likewise provided for the safe handling, storage and shipping of radioisotopes of various energies.

NAVORD-3803

Modine Norman
A WIDE BAND FILM DOSIMETER,
US Naval Ordnance Laboratory, White Oak, Maryland, September 20, 1954, 15 pp.

NAVORD Report 3803 summarizes the development and engineering tests of a wide band film dosimeter for X- and gamma-rays. This development was based on a study of photoelectric interactions reported in NAVORD Report 2990.

NBS-1003

White Gladys R
X-RAY ATTENUATION COEFFICIENTS FROM 10 KEV TO 100 MEV,
National Bureau of Standards, Washington, D.C., May 13, 1952, 93 pp. (39 refs).

This report constitutes the first item of a contemplated series of surveys and tabulations of information on various problems of radiation physics.

The work pertaining to this report was initiated as a part of a project on the penetration and diffusion of X-rays supported by the Office of Naval Research. The broader program outlined above was established on October 1, 1950, with the support of the Biophysics Branch, Division of Biology and Medicine of the Atomic Energy Commission.

NBS-2091

Brown Giles E
COBALT 60 RANGE FOR THE CALIBRATION OF DOSE AND DOSE RATE METERS,
National Bureau of Standards, Washington, D.C., December 2, 1952, 45 pp.

The description and evaluation study of a prototype model of a Cobalt-60 Calibrating Range given represents a portion of the joint Army-Navy-Air Force program carried out in the Radiation Physics Laboratory of the National Bureau of Standards under Contract Numbers AFPO-(38-038)51-4263E; APO-41-PHIBP-56-6; and NPO-298-1/18/51. The Cobalt-60 Calibrating Range was developed by NBS at the request of Bureau of Ships, to provide a means of calibrating dose rate meters with ranges varying from 0.5 milliroentgen per hour to 500 roentgens per hour using a single radioactive cobalt source. The present report is concerned with a description of this prototype model of the Calibrating Range and its characteristics.

NBS-4091

Caswell R S and Day F H
CALIBRATION OF FAST NEUTRON SURVEY METERS MODEL FN-1 MANUFACTURED BY NUCLEONIC COMPANY OF AMERICA,
National Bureau of Standards, Washington, D.C., May 5, 1955, 9 pp.

The Nucleonic Company of America FN-1 fast neutron survey meter consists of a "Hornyak button" (ZnS dispersed in lucite) scintillator with associated photomultiplier tube and counting rate meter. Five instruments were submitted for test by the Radiation Instruments Branch, US Atomic Energy Commission.

In principle, this instrument possesses the advantages of high neutron sensitivity and gamma discrimination, coupled with the disadvantage of having a response which is not simply related to neutron dose.

This article covers the fast neutron and gamma calibration of this instrument.

NBS-4726

Ehrlich Margaret
PHOTOGRAPHIC DOSIMETRY FINAL REPORT NOVEMBER 1, 1954 TO JUNE 30, 1954,
National Bureau of Standards, Washington, D.C., July 31, 1956, 10 pp.

The work done during the past contract period comprised research and development as well as calibrations in connection with Signal Corps atomic test procedures. This report summarized the results of the following studies:

1. Research and Development
   a. The photographic reciprocity law for X-rays in the ascending and reversal branches of characteristic curves.
   b. Extension of the usefulness of the NBS dosimeter to X-ray energies below 80 kev.
   c. Application of stabilization processing to photographic dosimetry between 200 r and 10,000 r.

2. Calibration - Film dosimeter calibration for the 1955 and 1956 atomic test series.

3. Publications, Lectures, Reports, and Conferences.

NBS-5150

Brueckmann R E and Barrans P V
TEST OF THREE ATOMIC INSTRUMENT COMPANY MODEL-414 SURVEY METERS,
National Bureau of Standards, Washington, D.C., February 11, 1957, 21 pp.

The studies covered by this report represent a portion of the program being carried out in the Radiation Physics Laboratory of the National Bureau of Standards for the Radiation Instruments Branch of the Atomic Energy Commission. The general purpose of the program is to evaluate new radiac instruments and other radiation-detecting and measuring elements with particular regard to their response over a wide range of dose rates and spectral energies of the incident radiation. The tests may also include other factors of specific interest pertinent to the general suitability of radiation-detecting instruments. The present report covers a study of three Atomic Instrument Company Model-414 survey meters to X-rays and gamma rays under a variety of conditions.

NBS Circular-499

NUCLEAR DATA,
National Bureau of Standards, Washington, D.C., September 1, 1950, 309 pp.

A collection of experimental values of half-lives, radiation energies, relative isotopic abundances, nuclear moments, and cross sections.

NBS Circular-499 (Suppl 1)

NUCLEAR DATA,
National Bureau of Standards, Washington, D.C., April 25, 1951, 56 pp.

A collection of experimental values of half-lives, radiation energies, relative isotopic abundances, nuclear moments, and cross sections.

NBS Circular-499 (Suppl 3)

NUCLEAR DATA,
National Bureau of Standards, Washington, D.C., June 9, 1952, 66 pp. (6 refs).

A collection of experimental values of half-lives, radiation energies, relative isotopic abundances, nuclear moments, and cross sections.

NCE-0858

Houston R Wayne
FAST NEUTRON DOSIMETRY IN PILE IRRADIATIONS,
University of Pennsylvania, Philadelphia, Pa. Paper published in Nuclear Science and Engineering, Vol. 4, pp. 227-238, August (1958).

For samples exposed in high neutron flux regions of reactors, the contribution to the total dosage due to the recoils from elastically scattered fast neutrons may be significant. The calculation of this contribution is considered. Three methods are presented, each differing in the manner in which the details of the energy distribution of fast neutrons are treated. In the first, the neutron flux per unit energy interval is assumed to be of the asymptotic or 1/E form up to fission energies. In the second and third, a separate computation is made for the uncollided neutrons reaching the sample. The remaining contribution due to once-scattered neutrons is treated as in the first method, but alternate forms for the source spectrum of once-scattered neutrons are considered. Use of the equations requires only a knowledge of the thermal neutron flux in the vicinity of the sample. Assumptions and limitations are discussed.

NCSC-109

Waltner Arthur
SCINTILLATION COUNTER GAMMA RAY MEASUREMENTS,
North Carolina State College, Contract No. DA-36-034-ORD-1656, September (1955),
11 pp. (3 refs).

Two general types of measurements were made at the Raleigh Research Reactor involving the use of thallium activated NaI in conjunction with a RCA-5819 photomultiplier as the radiation detector. In the first measurement, time exposures were made of an oscilloscope screen and gamma-ray energies deduced from the photoelectric lines observed in the photograph. Densitometer measurements were made of some of the negatives in order to make more accurate measurements of the position and relative intensity of the lines.

In the second set of measurements no photographs were taken. The discriminator output of a linear amplifier was fed to a scaler, and counting rates were observed at different discriminator settings. In this way it was possible to count only those events which dissipate an amount of energy in the crystal equal to or greater than the set values.

NDA-12-18

Certaine J, et al.
PENETRATION OF NEUTRONS FROM A POINT FISSION SOURCE THROUGH CARBON AND HYDROCARBONS,
Nuclear Development Corporation of America, White Plains, New York, June 30, 1956,
12 pp. (6 refs).

Moment calculations have been performed to study the penetration of fission spectrum neutrons through carbon and hydrocarbons. For pure carbon, the neutron spectrum as a function of penetration depth and the "age" to 1.44 ev have been determined. For hydrocarbons having the formulae CH, $CH_{1.9}$, $CH_{2.0}$, and $CH_{2.1}$, the fast neutron dose has been determined as a function of penetration depth and an effective removal cross section of carbon has been evaluated.

NESC-57-35

Gray Truman S, et al.
SOLID-STATE NEUTRON-FLUX MEASURING SYSTEM,
Published by The American Society of Mechanical Engineers, for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 8 pp. (6 refs).

A neutron-flux measuring system for nuclear-reactor control that comprises only solid-state devices is described. It consists of a fast-responding boron-impregnated thermopile driving a magnetic modulator which feeds a transistor amplifier. The modulator is excited by a low-distortion transistor oscillator.

NESC-57-36

Whitehouse David R and Replogle Frank S, Jr.
ACOUSTIC IONIZATION DETECTOR,
Massachusetts Institute of Technology, Cambridge, Massachusetts and Schlumberger Well Surveying Corporation, Ridgefield, Connecticut. Published by The American Society of Mechanical Engineers, for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 6 pp. (3 refs).

A unique a-c ionization chamber is described utilizing the acoustic pressure generated within an ionized gas by an applied a-c field. On the basis of preliminary theory an experimental neutron-sensitive chamber was designed. The instrument has an approximate sensitivity of 1.5×10^7 neutrons/cm^2/sec and proves to be rugged and fast.

NESC-57-39

Weaver C V, Smith C K and Chastain J W
THE DEVELOPMENT OF A THERMAL-NEUTRON-FLUX-MEASURING INSTRUMENT,
Battelle Memorial Institute, Columbus, Ohio. Published by The American Society of Mechanical Engineers, for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 8 pp.

An instrument to measure thermal-neutron flux directly and automatically, independent of gamma flux and ambient temperature. The method depends upon balancing the temperatures of an electrically heated balancing element and a fission-healed, uranium fuel sensing element. The flux-detector assembly measures only 3/16 inch OD by 4 inches long. The device was designed to measure flux in the range of 10^{13} to 10^{14} neutrons/cm^2/sec, with a detector life of 100 hours at an average flux of five 10^{13} neutrons/cm^2/sec at an ambient temperature of 600°F, with self-compensation for temperature changes and gamma flux.

A comparison of results with foil detectors showed a maximum instrument error of about 6%. Design considerations and circuitry are included.

NESC-57-40

Klickman Alton E and DeFalco Francis R
A WIRE-ACTIVATION TECHNIQUE FOR REACTOR-FLUX-PROFILE MEASUREMENTS,
Battelle Memorial Institute, Columbus, Ohio and Westinghouse Electric Corporation, Bettis Site, Pittsburg, Pa. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 4 pp.

The application of the wire-activation technique was extended so that flux profiles could be obtained in the cores of reactors of the pressurized water type. Tests with magnesium-0.01 a/o indium 0.010 inch in diameter showed that the method is feasible and the counting rates are high enough to give reliable results.

NESC-57-61

Johnson L E
EVOLUTION OF NEUTRON SENSING ELEMENTS - SCIENTIFIC LABORATORY TO INDUSTRIAL APPLICATION,
Neutronics Laboratory, Tinley Park, Illinois. Published by the American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 8 pp. (1 ref).

General types of neutron-sensing elements are proportional counters, scintillation counters, corona counters, pulse chambers and ionization chambers. (Scintillation and corona counters are not discussed.) The use of B^{10} and U^{235} is discussed. Diagrams and description of the ranges of usefulness are included.

NESC-57-70

Stone Richard S, Dr.
RECENT DEVELOPMENTS IN NUCLEAR INSTRUMENTATION AT THE KNOLLS ATOMIC POWER LABORATORY,
General Electric Company. Published by the American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 5 pp. (6 refs).

This report is a review of recent developments in the field of nucleonic instrumentation as concerns neutron and reactor physics. Systems are described, as in use at the Knolls Atomic Power Laboratory. The critical assembly and test reactor system utilizes ion-chambers for monitoring. Two instrumentation systems that have recently been developed for reactor and neutron physics experiments are described. The first is an automatic neutron flux scanner, and the second, a neutron time of flight spectrometer. Both of these systems utilize IBM programming and unique circuitry.

NP-3237 (No. 4)

Magee John L
THEORY OF RADIATION CHEMISTRY - I. SOME EFFECTS OF VARIATION IN IONIZATION DENSITY,
Department of Chemistry, University of Notre Dame, South Bend, Indiana, 16 pp. (14 refs).

The ionization density in a homogeneous medium exposed to steady irradiation is a function of space and time. The space-time ionization density pattern depends on both the ionization density of the particles used in the irradiation and also the number of particles incident per unit time and area (i.e., the rate of irradiation). In this paper, a simple model is presented which describes the life of a particle track in the steady-state condition and thus also gives a description of the variations in ionization density. The model has a satisfactory physical basis and has the particular advantage that mathematical treatment can be carried out rigorously. In our model, account is taken of the background ionization density which is present when a track is formed; this background

ionization density can be higher or lower than that of the track itself, depending upon the diffusion rate of the ions and radicals formed, their recombination rate constants, and the rate of irradiation. Yields in radiation chemistry depend upon whether the background is high or low; this situation is discussed in terms of the model with application to some problems of radiation chemistry.

NP-3238

REPORT OF SYMPOSIUM IV CHEMISTRY AND PHYSICS OF RADIATION DOSIMETRY - PART II,
Conducted by Technical Command, Army Chemical Center, Maryland, September 18-20, 1950, 101 pp.

This report covers services needed for a field-type dosimeter. The papers presented cover such topics as chain reactions for dosimeters, crystal dosimeters, and the conduction crystal dosimeter.

NP-3824

Evans Robley D
PROBLEMS ASSOCIATED WITH THE TRANSPORTATION OF RADIOACTIVE SUBSTANCES, Massachusetts Institute of Technology, (1951), 69 pp.

Radioactive materials present a wide variety of problems in packaging, handling, storage, and transportation. The potential hazards in handling these materials were recognized long ago. Methods for controlling these hazards have been developed for a number of special cases, and the general principles underlying adequate protection have been worked out.

Packages which contain radioactive materials emitting penetrating gamma rays or neutrons present the unique storage and transportation problem of a parcel which exerts action at a distance. Parcels which meet all the best standards of rugged and workmanlike packaging in the field of ordinary merchandise may nevertheless emit sufficient external radiation to be hazardous.

The quantitative evaluation and control of these potential hazards involve the compilation and evaluation of fundamental data on the nuclear properties of radioactive substances and on the interaction of various types of radiation with shielding materials, with photographic materials, with navigation instruments, and with living organisms. The material which follows is believed to contain all the currently available pertinent information in these several fields. Many of the quantitative data are new, and come from measurements or calculations by members of the National Research Council's Subcommittee on the Shipment of Radioactive Substances.

This subcommittee acted as advisor to the Bureau of Explosives in formulating the present Interstate Commerce Commission's regulations governing the packaging, stowage, and transportation of radioactive materials. These regulations are discussed in Section IX together with the technical reasons for each item in the regulations. As the ICC regulations are subject to amendment, the material presented here should form a guide to the wisdom of various proposed amendments.

Especially in the last year, the international shipment of radioactive materials has increased greatly. To provide smooth and uninterrupted international transportation by air, water, and ground, the regulations need to be similar in all countries involved. The ICC regulations have already been adopted verbatim by Canada. British regulations are now being formulated. The data presented here will permit the responsible boards overseas to make their own appraisal of the validity of the decisions underlying the ICC regulations. Similarly, those who must formulate, enact, and administer regulations governing shipment by mail, water or air transport should find their task shortened.

The nuclear data and methods of calculating shielding requirements which are presented in Section VIII should be a useful guide to those who are responsible for the packaging and shipment of radioactive materials.

The biological data of Section VI are compiled as a convenience especially to commercial producers and shippers of radioactive materials, whose legal departments requested proof of the advisability of imposing upper limits on the surface radiation from finished parcels.

The quantitative data of Section V on photographic materials also include some data not previously available in the literature, and may be a useful guide to the manufacturers, shippers, and users of photographic materials.

NP-4002

INTERIM DEVELOPMENT REPORT FOR PHOSPHATE GLASS GAMMA-RADIATION DOSIMETER,
Polaroid Corporation, Research Department, 730 Main Street, Cambridge 39, Mass., Contract No. NObsr-49257, July 15, 1952, 18 pp.

Silver phosphate glass has the peculiar property of emitting orange fluorescent light when irradiated with near-UV radiation, provided the glass has first been exposed to gamma radiation. Since the intensity of the fluorescence is more or less proportional to the gamma radiation dose, the glass may be used as the gamma radiation-sensitive unit of a gamma radiation dosimeter.

As of June 1, 1952, the properties of the 8% silver phosphate glass itself had been explored fairly extensively and found to be satisfactory in all principal respects. A thousand complete dosimeters (DT-60(XN-3)/PD) had been made and approximately 700 had been delivered to BuShips. Also, an acceptable design of "laboratory-type" reader (CP-95(XN-3)/PD) had been completed and five units had been constructed and delivered to BuShips.

The principal remaining task is to increase the accuracy of the laboratory-type readers, improve the uniformity of performance from one reader to another, improve the standards, and generally assist in matters basic to various production programs getting underway.

NP-4400

Berry Myron G and Linschitz Henry
NON-ELECTRONIC DOSE RATE INDICATING SYSTEMS - SECOND QUARTERLY PROGRESS REPORT, SEPTEMBER-DECEMBER, 1952,

Institute of Industrial Research, Syracuse University, Syracuse 10, New York, Contract No. DA-36-039 SC-15533, (1952), 90 pp.

This project is concerned with a fundamental study of radiation-sensitive systems, with the ultimate goal of developing a suitable nonelectronic dose rate indicating device. The first phase of the work is a systematic and complete survey of the literature with particular emphasis on the search for systems showing promise for use in the above application, and the preparation of a suitable bibliography. Later phases will involve research on and evaluation of suitable radiation-sensitive systems or devices.

References are listed concerning the following topics:

Color changes - 8 pages
Luminescence - 12 pages
Theory of luminescence and coloring of alkali halides - 2 pages
Calorimeteric effects - 3 pages
Electrical effects - 3 pages
Radiation effects on catalysis and absorption - 1 page
Effects on colloids - 2 pages
Chemical effects - 7 pages

NP-4703

Burgwald G M and Reiffel L
FUNDAMENTAL STUDIES ON SCINTILLATION PHOSPHORS,
Armour Research Foundation, 35 West 33rd St., Chicago 16, Illinois, Contract No. AF18(600)-352, July 9, 1953, 56 pp.

This report describes a study of the nature of afterflow in inorganic scintillation phosphors when bombarded by high-energy gamma radiation. The afterflow characteristics of several of the more important scintillation phosphors were studied, both under standard conditions and under variable temperature and pressure. All of the important inorganic phosphors studied exhibit varying degrees of afterglow, and in cases where the level of activity being measured varies by order of magnitude, the effect of residual light from the crystal becomes important.

NP-5574

Whitehouse David R
A-C IONICATION DETECTOR,
Servomechanisms Laboratory, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass., Contract No. N5ori-07876 NR-025-164, January 31, 1955, 69 pp. (10 refs).

This report describes a rugged and fast ionization chamber for the detection of neutron flux in a nuclear reactor. The theory is developed for a rather unique type of a-c chamber utilizing the acoustic pressure generated within the ionized gas by an applied a-c field. On the basis of this theory and preliminary experiments, a neutron-sensitive chamber was designed and constructed, then tested in neutron flux. The instrument proves to be rugged and fast, but its reliability is undetermined at this time. The experimental chamber has a minimum detectable flux level of 1.5×10^7 n/cm^2/sec, a dynamic range of 20 to 1 (2000 to 1 estimated as attainable), and a time response of 2 milliseconds.

NP-5625

Replogle Frank S, Jr. and Harbourt C O
A STACKED-DISK NEUTRON THERMOPILE,
Servomechanisms Laboratory, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass., Contract No. N5ori-07877, March 15, 1955, 127 pp. (10 refs).

This report describes the theory, design, construction, and testing of a thermopile sensitive to slow neutrons. Design techniques are presented for a new, mechanically rugged configuration, which enables a fast or slow time response to be achieved with optimum electrical power output. Construction and testing details are given for a thermopile having a response time of 37 milliseconds and an internal resistance of 0.7 milliohm. The power output in a flux (unperturbed) of 3.8×10^{12} n/cm^2/sec was 21 microwatts.

A treatment of the spurious responses of this type thermopile is presented in an Appendix by Cyrus O. Harbourt.

NP-5676

Seed R G and Withey E L, Jr.
BATTERYLESS DOSE RATE INDICATOR,
Scientific Specialties Corporation, Snow and Union Streets, Boston 35, Mass., Contract No. DA-36-039 SC-52581, (1955), 29 pp.

This seventh quarterly report, covering work for the months of December 1954, January 1955, and February 1955 on a batteryless dose rate indicator, contains a brief description of: (1) self-generating theory and cells, (2) large area germanium self-generating cells, (3) Model VI hand generator, and (4) circuitry for possible use with hand-powered generators.

An analysis of self-generating theory and experience indicates, as previously estimated, that the most promising material is a germanium n-p junction. Further experiments with large area alloyed junctions yield outputs of substantial proportions, but not sufficient in view of price and difficulty of fabrication to fabricate a completed field-type, self-generating instrument.

NP-5750

Gray T S and Van Rennes A B
ANNUAL PROGRESS REPORT,
Servomechanisms Laboratory, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass., Contract No. N5ori-07876, March 1, 1955, 54 pp.

Efforts of the Electronic Nuclear Instrumentation Group have been directed chiefly toward completing the development of a rugged, wide range, fast responding, neutron-flux measuring system that is free of fragile, short-life vacuum tubes. The first experimental model of the neutron-sensitive thermopile was completed and tested in the Brookhaven reactor. Likewise the components for amplifying the output of the thermopile, including the magnetic modulator and the tuned transistor amplifier, have been developed into a working system and tested. A new transistorized oscillator of extremely low second-harmonic output for use as a power supply for the modulator has been evolved.

Meanwhile, a preliminary model of the acoustic ionization chamber was completed and tested in the Brookhaven reactor. The study of pulse height analysis systems was completed and the advantageous features of a system employing photographic film for data storage demonstrated. Statistical study of the fluctuations in period-meter indications viewed as a stochastic process has been continued, and an analysis of multielement logarithmic devices for use in period-indicating systems has been started.

NP-6039

Hollander Lewis E, Jr.
RESEARCH AND DEVELOPMENT OF PHOTOCONDUCTIVE DOSE RATE INDICATOR FOR IONIZING RADIATIONS,
The Victoreen Instrument Company, 5806 Hough Avenue, Cleveland 3, Ohio, Contract No. DA-36-039 SC-70150, April 30, 1956, 17 pp. (Appendix 15 pages).

The object of this contract is to develop a portable gamma detecting radiactmeter employing a photoconductive crystal as a detecting element. The equipment shall be battery powered and require no additional amplification.

The emphasis in this quarter is principally embodied by Phase II of this contract. A procedure for applying ultrasonic soldered indium electrodes to CdS crystals was developed.

NRL-MEMO-266

Schulman James J
MEASUREMENT OF HIGH DOSES OF CO^{60} GAMMA-RAYS BY ABSORPTION CHANGES IN PHOSPHATE GLASS,
Solid State Division, Naval Research Laboratory, Washington, D.C., February (1954), 22 pp. (4 refs).

It is concluded that the phosphate glasses, particularly the silver-activated glass, are suitable for dosimetry of doses from a few thousand roentgens to a few million roentgens, encompassing the dose range used in trychinosis control, pasteurization, and sterilization. Use of this glass for dosimetry offers the advantage of ease of use, ruggedness, and immediate availablility in large numbers with uniform sensitivity and at comparatively low cost.

NRL-MEMO-309

Rabin Herbert
FUEL ELEMENT DOSIMETRY BY ABSORPTION CHANGES IN SILVER ACTIVATED PHOSPHATE GLASS,
Solid State Division, Naval Research Laboratory, Washington, D.C., June 7, 1954, 16 pp. (5 refs).

A series of experiments were performed to determine the effectiveness of using the optical density changes of silver activated phosphate glass in monitoring the time dependent, high rate gamma fields of spent uranium fuel elements. These experiments were performed at the Materials Testing Reactor in Idaho. The results indicate that the response of the glass to fuel element irradiation is independent of both fuel element age and irradiation rate over the range of the experimental data obtained, and that by performing an initial calibration in the fuel element field, this glass may be advantageously used in fuel element dosimetry.

While this work is incomplete, this paper gives some information on changes of sensitivity of glasses in Co^{60} radiations vs fuel element radiations, and on fading after exposure.

NRL-Q-1(2)

Schulman James H, et al.
DOSIMETRY OF X-RAYS AND GAMMA-RAYS BY RADIOPHOTOLUMINESCENCE,
Journal of Applied Physics, Vol. 22, No. 12, pp. 1479-1487, December (1951).

The effects of high energy radiation on the luminescence properties of solids are surveyed. Of the four effects considered--radiophotoluminescence, radiophotostimulation, radiothermoluminescence, and the "killing" of luminescence by X-rays or gamma-rays--the first effect is shown to have advantages in principle over the others as a basis for dosimetry.

The absorption, excitation, emission, sensitivity, energy dependence, and stability characteristics of a radiophotoluminescent Ag-activated phosphate glass are described. It is shown that dosage measurements can be made with this material, employing a simple fluorophotometer, from 10 roentgens to a few thousand roentgens of gamma-rays. By proper shielding, such a dosimeter element can be made reasonably independent of energy. The dosage indication obtained is quite stable with time and is not seriously affected by exposure of the glass to visible or ultraviolet light or to temperatures in the range of -70 to +100°C. Because of its sensitivity range and its stability over a wide range of ambient conditions, the dosimeter appears to be particularly suited for monitoring personnel that may be exposed to rather high doses of gamma-rays, such as may be encountered in A-bomb explosions.

NRL-Q-1(4)

Schulman James H, et al.
RADIOPHOTOLUMINESCENCE DOSIMETRY SYSTEM OF THE U.S. NAVY,
Nucleonics, Vol. 11, No. 10, pp. 52-56, October (1953), (9 refs).

This dosimeter, utilizing Ag-activated phosphate glass, has a range of from 10 r to at least 600 r. Response is linear and independent of dose rate up to at least 170 r/min. Energy dependence is diminished by lead filters.

NRL-Q-1(6)

Schulman James H, et al.
MEASURING HIGH DOSES BY ABSORPTION CHANGES IN GLASS,
Nucleonics, Vol. 13, No. 2, pp. 30-33, February (1955), (7 refs).

Changes in optical density of glass measure doses up to 2×10^6 rep with 5% accuracy independent of dose rate. Dosimeter is convenient (1 x 1 x 0.3-cm plate) and rugged. Standardizing measurement time or heat treatment solves problem of fading.

NRL-Q-1(8)

Schulman James H, et al.
APPLICATION OF LUMINESCENCE CHANGES IN ORGANIC SOLIDS TO DOSIMETRY,
Journal of Applied Physics, Vol. 28, No. 7, pp. 792-795, July (1957), (10 refs).

The degradation of photoluminescence in anthracene and in naphthalene has been studied under gamma-ray and electron irradiation over the range 3×10^5 to 2×10^8 rep. For both materials the variation of brightness with Co^{60} gamma-ray dose D, in rep, may be represented by $(I/I_0) = (1 + AD)^{-1}$, where $A = 8.5 \times 10^{-7}$ for anthracence and $A = 14 \times 10^{-7}$ for naphthalene, with emission in the visible spectral region. Both the degradation and radiophotoluminescence are stable with time at room temperature. The employment of these effects for dosimetry is discussed.

NRL-Q-1(10)

Schulman James H
SOLID STATE DOSIMETERS FOR RADIATION MEASUREMENT IN FOOD PROCESSING,
Solid State Division, Naval Research Laboratory, Washington, D.C.

Exposure to ionizing radiation can produce changes in a number of the physical properties of insulating solids. Changes in optical properties--specifically in absorption and luminescence--are especially striking with some materials, and these effects have been extensively investigated for application to dosimetry. The dose range that is accessible to the various solid-state devices depends upon the phenomenon employed. Some solid-state systems are capable of detecting the order of milliroentgens, while others can indicate in the range of 10^8 R or higher. This brief survey concerns itself primarily with systems capable of measuring high doses, say of the order of 10^4 roentgens to 10^7 roentgens, since only these are of concern in the radiation treatment of food. However, in order to illustrate the enormous range of applicability of solid-state systems, brief mention will be made of effects used for the measurement of lower dosages as well.

NRL Report 4062

Schulman James H, Ginther Robert J and Kirk Russell D
DOSIMETRY OF IONIZING RADIATIONS BY MEANS OF COLOR CENTERS IN SENSITIZED ALKALINE-EARTH SALTS,
Naval Research Laboratory, Washington, D.C., October 13, 1952, 17 pp. (6 refs).

The relationship of lattice defects--particularly vacancies and impurity ions--to the X-ray-induced discoloration of alkali-halide crystals is briefly reviewed. These concepts are then extended to alkaline-earth salts, leading to the prediction that such salts should be more easily discolored by ionizing radiations if they are "sensitized" by the incorporation of monovalent positive-ion impurities. This prediction is confirmed experimentally by addition of various alkali-ion impurities to a number of alkaline-earth compounds. The "sensitization" is particularly effective with strontium sulfate.

Crude dosimeters made from sensitized strontium sulfate are described. It is found possible to distinguish between doses of 0, 50, 100, 200, and 400 roentgens of radium gamma rays by simple visual inspection of these dosimeters.

NSE-0558

Titus Frank
MEASUREMENT OF THE GAMMA-RAY DOSE NEAR THE INTERFACE BETWEEN TWO MEDIA,
Nuclear Science and Engineering, Vol. 3, No. 5, pp. 609-619, May (1958), (9 refs).

Measurements have been made of the distribution of exposure dose in the neighborhood of a plane boundary separating two media of very different density: steel-wool and steel. A point-isotropic Co^{60} source was located in the vicinity of the boundary. Control measurements were performed in a homogeneous medium of steel-wool. In this way the effect on gamma-ray propagation of an abrupt density change was established. The amin result was a progressive decrease of exposure dose near the density-interface compared with the homogeneous medium situation, as the source-detector distance was increased. There is good agreement between the experimental results and corresponding Monte Carlo calculations.

NSE-0858-1

Houston R Wayne
FAST NEUTRON DOSIMETRY IN PILE IRRADIATIONS,
Nuclear Science and Engineering, Vol. 4, No. 2, pp. 227-238, August (1958), (14 refs).

For samples exposed in high neutron-flux regions of reactors, the contribution to the total dosage due to the recoils from elastically scattered fast neutrons may be significant. The calculation of this contribution is considered here. Three methods are presented, each differing in the manner in which the details of the energy distribution of fast neutrons are treated. In the first, the neutron flux per unit energy interval is assumed to be of the asymptotic or 1/E form up to fission energies. In the second and third, a separate computation is made for the uncollided neutrons reaching the sample. The remaining contribution due to once-scattered neutrons is treated as in the first method, but alternate forms for the source spectrum of once-scattered neutrons are considered. Use of the equations requires only a knowledge of the thermal-neutron flux in the vicinity of the sample. Assumptions and limitations are discussed. Numerical results are presented for comparison of the effects in light water, heavy water, and graphite moderated reactors in the irradiation of a hydrocarbon (cyclohexane) sample.

NYO-3345

Proctor Bernard E, Goldblith Samuel A and Davison Sol
STUDIES ON GLASS DOSIMETERS,
Final report for the period July 1, 1954 through June 30, 1955, Massachusetts Institute of Technology, Cambridge, Mass., Contract No. AT-(30-1)-1164, (1955), 69 pp. (11 refs).

This report covers the theoretical aspects of glass dosimeters with limited experimental results covering stability of glass after irradiation, effect of heat treatment, and details of fading.

NYO-3782

Kreidl N J and Blair G E
IRRADIATION DAMAGE TO GLASS,
Bausch & Lomb Optical Co., Rochester, New York, Contract No. AT-(30-1)-1312, March 21, 1955, 21 pp.

A system of high level dosimetry (of high energy radiation) utilizes the absorption changes in glasses measured on a suitable spectrophotometer. Calibration has been accomplished over the range of 1.5×10^3 to 4.1×10^6 rep.

NYO-7298

Chang Roger
FUNDAMENTAL STUDIES OF THE MECHANISM OF RADIATION DAMAGE,
Technical Report No. 1, Rutgers University, New Brunswick, New Jersey, Contract No. AT-(30-1)-1730, December 31, 1955, 16 pp. (5 refs).

The operational characteristics of the Hilger micro-focus X-ray diffraction unit is described. Application of micro-focus X-ray diffraction analysis to the studies of polycrystalline copper, nickel, and diamond with and without neutron irradiation is reported. Significant differences are found between irradiated and unirradiated Cu, Ni specimens by means of the micro-focus X-ray diffraction technique. The report includes X-ray rocking curve studies of diamond and germanium single crystals and grain size measurements of polycrystalline Cu and Ni specimens with and without neutron irradiation.

NYO-8531

Bray P J and Williams A O, Jr.
RADIATION DAMAGE STUDIES USING THE TECHNIQUES OF ELECTRON-SPIN PARAMAGNETIC RESONANCE,
Department of Physics, Brown University, Providence, R.I., Contract No. AT-(30-1)-2024, March 10, 1958, 6 pp. (10 refs).

A Varian V-4500 electron-spin paramagnetic resonance spectrometer and associated 6-inch electromagnet have been placed in operation. Measurements of the magnetic field are made with a Pound-Watkins spectrometer constructed in the laboratory.

Studies have been made of single crystals of LiF which have received thermal-neutron irradiation dosages up to 72 hours in a flux of $2.3 \times 10^{12}/cm^2$-sec. The observed resonance envelope and hyperfine splittings are not in agreement with F-center theory. A dependence of the hyperfine splitting on crystal orientation in the magnetic field has been noted. Crystals of KCl, KBr, KI, NaF, NaCl, RbI, CsBr, and CsI which have received reactor or gamma irradiation are under investigation.

Samples of alkali silicate and borate glasses have been prepared and are currently receiving neutron and gamma irradiation.

Crystals of KN_3 and NaN_3 are being grown and will be studied after irradiation. Preliminary investigations are in progress on powders of these azides.

Studies of synthetic corundum (Al_2O_3), spinel ($MgO\,3.3\,Al_2O_3$), and rutile (TiO_2) are being started.

A copy is appended on an abstract entitled "Paramagnetic Resonance in Neutron-Irradiated LiF" submitted for presentation at the 1958 Washington meeting of the American Physical Society.

ONRL-48-52

Mooney R W and Szasy G J
DISCUSSION ON RADIATION CHEMISTRY,
Office of Naval Research London, London, England, May 26, 1952, 13 pp.

A general discussion on "Radiation Chemistry" was held by the Faraday Society at Leeds on April 8-10, 1952. A large number of topics fundamental to radiation chemistry were dealt with, and the discussions revealed the critical state in which this subject finds itself at the present time. Most of the basic techniques and fundamental standards still need final definition and standardization.

The advantages of chemical dosimetry have led to a revival of the interest in these procedures. In aqueous systems the sulfuric acid solution of ferrous sulfate is generally accepted as most suitable, at least for relatively low dose rates.

Professor Bacq has discovered that a number of amines can protect mice from the lethal effect of X-rays when milligram quantities are injected prior to irradiation. Injection after exposure was found to be useless.

ORNL-711

Gossick B R and Henry K
NEUTRON ENERGY SPECTROMETER,
Shielding Section, Reactor Technology Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, June 12, 1950, 13 pp.

This report discusses a neutron energy spectrometer and points out that by employing a proportional counter of special design, it is possible to make a fast neutron spectrometer with which the energy distribution can be obtained without taking derivatives of the counting rate. To avoid differentiating the counting rate, it is necessary to know both the range and angle of the recoil within acceptable errors. By virtue of biasing a linear pulse amplifier to take advantage of the peak in the Bragg specific ionization curve, only those recoils are counted which traverse a given thickness of stopping material through a collimator and then end their path near a short anode. Thus the range is associated directly with the number of counts. It is, of course, necessary to know the direction of the incident neutrons, so that the limits of the recoil angle are defined by the collimator.

ORNL-865

Snell A H and Wollan E O
QUARTERLY PROGRESS REPORT FOR PERIOD ENDING SEPTEMBER 20, 1950,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7504-Eng-26, January 8, 1957, 107 pp.

This is a progress report. The topics presented are listed and summarized below: Short-Lived Isomers, Short-Period Activities, Scintillation Spectrometry, Nuclear Alignment, Neutron Diffraction, High-Voltage Accelerator Program, Search for a Permanent Electric Dipole Moment of the Neutron, Neutron Diffusion in Water, and Physics of Solids and Theory.

A number of problems have been treated by the theoretical physicists. The L-shell conversion problem has been reviewed relative to carrying out the computing-machine work. Several problems have arisen in connection with the work of the Particle Acceleration program, one of which is concerned with the angular dependence of γ emission from protons on B^{11}.

ORNL-1002

Darden Edgar B and Sheppard C W
A THIMBLE TYPE GAMMA-RAY DOSIMETER AND THE MEASUREMENT OF THE RADIATION FROM LUMPED AND DISTRIBUTED TYPE SOURCES,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, July 9, 1951, 57 pp. (21 refs)

Accurate physical measurements in radiation dosimetry are becoming increasingly important with the growing quantitative accuracy of techniques for studying radiation effects on living organisms. For B-ray work a precise method for the determination of surface ionization intensities of sources has been developed. In X-ray work up to 250 kvp, dosimetry studies have been carried out in this laboratory including calibrations of Victoreen condenser-type r meters against a standard free-air chamber. Based on these calibrations, a standard position was established inside a lead enclosure around a medium intensity Co^{60} source for periodically checking the various laboratory Victoreen chambers.

ORNL-1283

Gossick B R
GENERAL PRINCIPLES OF A PROTON RECOIL FAST-NEUTRON SPECTROMETER,
Physics Division, Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 28, 1952, 61 pp. (10 refs).

A general equation for calculating the neutron energy spectrum from proton recoil counting data is derived. This equation is optimized subject to a constant total error to determine the most favorable experimental conditions. Feasible accuracy is illustrated by presenting a family of curves of the counting time (required for one point on a spectrum) plotted against total error with source intensity as a parameter. The calculations apply only to a "good geometry" experiment with a point source. The subject is treated for the most part in terms of a thin radiator, but the calculations apply equally well for the case of a thick radiator by a simple extension which is outlined.

ORNL-1479

Cochran R G and Henry K M
A PROTON RECOIL TYPE FAST-NEUTRON SPECTROMETER,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April 20, 1953, 36 pp. (14 refs).

A triple coincidence-type proton recoil spectrometer has been developed for measuring neutron spectra of interest in shielding design. The instrument is composed of a triple-section proportional counter with suitable radiator-absorber wheels, amplifiers, electronic pulse height selectors, and a triple-coincidence circuit. The energy resolution is comparable to photographic plates which are at present the best method for neutron spectra measurements. Considerable effort has been made to obtain maximum sensitivity by optimizing the available parameters. The spectrometer calibration was checked by measuring monoenergetic neutrons from the ORNL Van de Graaff generator. Excellent agreement with calculations was obtained for both energy and intensity.

Several spectral measurements of polonium-beryllium and polonium-boron sources have been included in this report as examples of the type of measurements that can be obtained with this instrument.

ORNL-1763

Morgan K Z (Director)
HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT,
Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, September 27, 1954, 19 pp. (References).

This report describes work performed at ORNL in the Health Physics Division. The subjects investigated include the following: (1) passage of charged particles through plasma, (2) fast-neutron tissue dosimeters, (3) aircraft scintillation equipment, (4) spectrographic analysis of human tissue, (5) concentration experiments on mice, (6) an analytical procedure (radiochemical) for the determination of radioactive strontium in urine specimens, (7) film dosimetry, (8) airborne radioparticulate contamination, (9) radioactive waste disposal, and (10) process-waste-treatment studies.

ORNL-1783

Blomeke J O
NUCLEAR PROPERTIES OF U^{235} FISSION PRODUCTS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, November 2, 1955, 58 pp.

Tables are presented that list the U^{235} fission-product decay chains and the current best single values of their fission yields and cross section. The fission products are also tabulated according to decreasing order of half-life, thermal-neutron capture cross section, gamma energy, and beta energy.

ORNL-1879

Fowler J L and Wollan E O (Editors)
SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING MARCH 20, 1955,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 3, 1955, 71 pp. (References)

This report describes work performed at ORNL by the Physics Division. The subjects investigated include the following: (1) cross-section studies, (2) neutron diffraction studies, (3) heavy-ion physics, (4) low-temperature physics, (5) studies of the attenuation of reactor radiations by shielding, (6) control rod calibrations in the Bulk Shielding Reactor, and (7) cyclotron studies.

ORNL-1997

Borkowski C J (Director)
SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING JULY 31, 1955,
Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, February 1, 1956, 17 pp. (10 refs).

This report from the Instrumentation and Controls Division covers the following subjects:

1. Investigation of the response of scintillation and Cerenkov counters to the gamma radiations from a swimming-pool-type reactor,
2. Differential and integral pulse-height selector for the DD2 linear amplifier,
3. An A-C bridge for measuring low resistances,
4. An improved serial memory pulse-height analyzer,
5. High-voltage research,
6. Modifications and improvements to the Oracle,
7. Instrumentation for rocking-bomb experiments.

ORNL-2049

Morgan K Z (Director)
HEALTH PHYSICS DIVISION SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING JANUARY 31, 1956,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 3, 1956, 63 pp.

This report discusses work performed at ORNL by the Health Physics Division. Topics discussed in the fields of Applied Radiobiology, Sanitary Engineering Research, and Radiation Dosimetry, include: (1) Distribution and Excretion of Uranium in Man, (2) Ecology, (3) Urinalysis Research, (4) Distribution of Radioisotopes in Animal Tissue, (5) Isotopic Distribution in Man, (6) Chemistry and Soils Engineering, (7) Airborne-Radioactivity Studies, (8) Experimental Physics of Dosimetry, (9) Theoretical Physics of Dosimetry, and (10) Dosimetry Applications.

ORNL-2081-7

Silver E G
MEASUREMENTS OF THE THERMAL-NEUTRON FLUX FROM THE BSF THERMAL COLUMN,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

A thermal column with a geometrically uniform neutron beam is needed for numerous experiments. A thermal column which consists of a stack of graphite against which the reactor can be positioned has been built at the BSF. A 10-in. thick lead shield between the graphite and the reactor serves to attentuate the gamma-ray flux from the reactor. Foil measurements of the flux at the radiation port indicated that a uniform flux is available in an area of 4π in.^{2}.

ORNL-2081-16

Peelle R W, et al.
MEASUREMENT OF THE SPECTRUM OF SHORT-LIVED FISSION-PRODUCT DECAY GAMMA RAYS EMITTED FROM A ROTATING FUEL BELT,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

By means of a rotating belt containing U^{235}, the short-lived fission-product gamma rays have been measured with a three-crystal spectrometer. Rotation times as short as 1 sec have been used. A value for the total gamma-ray energy of 4.8 Mev for the 0.36- to 5.8-Mev photon energy interval was observed.

ORNL-2081-17

Zobel W and Love T A
TIME AND ENERGY SPECTRA OF FISSION-PRODUCT GAMMA RAYS MEASURED AT SHORT TIMES AFTER URANIUM SAMPLE IRRADIATIONS,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 7 pp.

The fast pneumatic tube at the ORNL Graphite Reactor has been used in conjunction with the three-crystal spectrometer to measure short-lived fission-product gamma rays for times after fission from 1.25 to 1600 sec. The total energy of photons in the interval 0.28 to 5.0 Mev was found to be 3.23 Mev ±25%. Spectra for various times after fission are given, from which it is anticipated that individual emitters can be identified.

ORNL-2081-20

Henry K M and Haydon M P
FISSION NEUTRON SPECTRUM OF U^{233},
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 3 pp.

The fission neutron spectrum of U^{233} was measured at the BSF with nuclear photographic plates under the same experimental conditions as those of earlier measurements with a proton-recoil neutron spectrometer. The shapes of the resulting spectra agreed within the combined limits of error.

ORNL-2081-21

Henry K M
FAST-NEUTRON SPECTRUM OF A 117-CURIE PO-BE SOURCE,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

Since Po-Be sources are used to calibrate fast-neutron dosimeters, the fast-neutron spectrum of such sources should be known. Recently, the availability of a source of larger physical size and intensity prompted a further measurement with the BSF proton-recoil spectrometer. The resulting spectrum agrees within statistical error with the spectra previously determined.

ORNL-2081-23

Dresner L
ESTIMATION OF RESONANCE INTEGRALS,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 5 pp.

Resonance parameters are known for quite a large number of nuclei. These parameters exhibit regular behavior throughout the periodic table. Based on this information, a systematics of resonance integrals has been constructed; estimated resonance integrals are compared with experimentally determined values.

ORNL-2081-24

Dresner L
HOMOGENEOUS EFFECTIVE RESONANCE INTEGRALS OF U^{238} AND TH^{232},
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 7 pp.

Numerical calculations performed on the Oracle have made possible exact inclusion of the effect of Doppler broadening of resonance lines in the calculation of homogeneous resonance absorption integrals. The effective resonance integrals of U^{238} and Th^{232} have been calculated as functions of the scattering cross section per absorbing nucleus for 0 and 300°K, using the theory of Wigner, et al. Agreement of the calculated (300°K) and experimental resonance integrals is excellent for U^{238} and good for Th^{232}, except for pure ThO_2, where a discrepancy is noted. The temperature coefficients for the metals have also been calculated, and a comparison with experiment is given. Finally, the effect of multiple scatterings in the lowest resonances has been investigated for pure U^{238} metal and found to be important.

ORNL-2081-25

Dresner L
EFFECT OF GEOMETRY ON RESONANCE NEUTRON ABSORPTION,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

By use of the theory of Wigner, et al., an expression has been derived, for the geometric dependence of the effective resonance integral of lumps, which is independent of the details of resonance structure (widths, resonance energies). This expression has been compared with experimentally determined geometric variations for U^{238} and Th^{232} and is found to overestimate the ratio of surface-to-volume absorption by about 40%. The cause of this overestimate is obscure, but its amount should be the same in all materials.

ORNL-2081-42

Guth E and deSaussure G
THEORY OF THE $C^{13}(\gamma, n)C^{12}$ REACTION,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

A theoretical investigation of the $C^{13}(\gamma, n)C^{12}$ reaction has led to the conclusion that, in contrast with the $Be^{8}(\gamma, n)Be^{8}$ reaction, there is no evidence of resonance right above the threshold. This causes the $C^{13}(\gamma, n)C^{12}$ cross section to become much smaller (by about a factor of 10) than the corresponding $Be^{9}(\gamma, n)Be^{8}$ cross section.

ORNL-2081-43

Trubey D K
ESTIMATION OF PHOTONEUTRONS FROM C^{13},
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 3 pp.

LTSF measurements of thermal-neutron flux in the presence of high-energy gamma rays in liquid media containing hydrogen, or carbon and hydrogen, indicate that photoneutrons comprise a large fraction of the total thermal-neutron flux at large distances from the neutron source. This is attributed chiefly to the (γ, n) reaction in C^{13}. Measurements in an oil medium with and without a bismuth slab to reduce the gamma rays, and consequently the photoneutrons which they produced, agreed with calculated fluxes.

ORNL-2081-48

Murray R B
FAST-NEUTRON SPECTROMETER DEVELOPMENT,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 6 pp.

A program is in progress that is aimed toward developing a fast-neutron spectrometer with a greater sensitivity than has been available heretofore. The types of spectrometers being considered are: (1) proton-recoil spectrometers, and (2) those in which the total energy released in a neutron-induced nuclear reaction is measured. For the latter the $Li^6(n,\alpha)H^3$ reaction (Q = 4.78 Mev) is being utilized.

ORNL-2081-49

Muckenthaler F J
INVESTIGATION OF THE HORNYAK BUTTON AS A FAST-NEUTRON DOSIMETER,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 9 pp.

In the interest of developing an improved fast-neutron dosimeter, an investigation of the Hornyak button as a dosimeter has been initiated. The button consists of a homogeneous mixture of fine Lucite and ZnS powder mounted on a phototube. The neutrons impinging upon the crystal collide with the protons present, and the recoiling protons excite the ZnS centers. These, in turn, emit photons that are detected by the photomultiplier tube. The response of the button to neutrons from Po-Be sources (the BSR, the TSR, and the Van de Graaff) is presented.

ORNL-2081-50

Love T A, et al.
INSTRUMENTATION FOR A GAMMA-RAY SPECTROMETER,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 6 pp.

In order to measure the time and energy spectra of short-lived fission-product gamma rays, it was necessary to modify the instrumentation for the BSF multicrystal gamma-ray scintillation spectrometer. The modifications in the existing equipment and the new equipment added to the system are described.

ORNL-2081-51

Zerby C D
PULSE-HEIGHT DISTRIBUTION FROM AN NA1(t1) CRYSTAL,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

A calculation of the relation between incident gamma-ray energy spectra and the pulse-height distribution from an Na1(t1) crystal used as a gamma-ray spectrometer has been started.

ORNL-2127, (Pt. II, Vol. 1) (TID-4500)

Blomeke J O and Todd Mary F
URANIUM-235 FISSION-PRODUCT PRODUCTION AS A FUNCTION OF THERMAL NEUTRON FLUX, IRRADIATION TIME, AND DECAY TIME,
Oak Ridge National Laboratory, Oak Ridge, Tenn., December 23, 1957.

This is a summation of individual chains, elements, and the rare-gas and rare-earth groups. Uranium-235 fission-product productions are arranged according to chain or mass number as a function of thermal flux, irradiation time, and decay time. 354 pages of tables are presented.

ORNL-2389-2

Reynolds A B and Johnson E B
COMPARISON OF THE DISTRIBUTED-POISON AND INHOUR METHODS FOR MEASURING REACTIVITY,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 7 pp. (8 refs).

The reactivity effect of a uniform distribution of boron carbide (B_4C) in the core of the BSR was determined experimentally by means of the inhour equation. A thin strip of B_4C-impregnated Plexiglas was inserted into each fuel element. As each strip was removed, the reactor period caused by its removal was measured and the reactivity worth of each B_4C strip was then obtained from the inhour equation. Since the ratio of the nonleakage probability of prompt neutrons to that of delayed neutrons appears in the inhour equation, the experimental results depended on the value chosen for this ratio. Two values for this ratio were calculated. The total reactivity effect of the distributed B_4C was calculated from the change in thermal utilization. The calculated value agrees with the experimental value within 10%, which was within the experimental error.

ORNL-2389-4

deSaussure G
CALCULATION OF THE PHOTONEUTRON FLUX IN THE WATER NEAR THE BULK SHIELDING REACTOR,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (5 refs).

The neutron flux observed in water at distances greater than about 200 cm from the BSR is essentially entirely attributable to photoneutron production in the naturally occurring deuterium of the water. By using measured gamma-ray spectra at 267 cm, the expected photoneutron flux is calculated and found to agree with observed values within 4%.

ORNL-2389-6

deSaussure G
CALCULATION OF THE GAMMA-RAY SPECTRUM OF THE BULK SHIELDING REACTOR,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (6 refs).

A hand calculation has been performed of the leakage-gamma-ray spectrum above 3 Mev for the BSR. Simplifying assumptions were straight-ahead Compton scattering, neglect of more than single scatterings, and uniformity of flux in the core. The calculated spectrum is significantly higher than the measured value in spite of the fact that the assumptions should lead to an overestimate. Further experiments and calculations are planned.

ORNL-2389-11

Fox J K, Gilley L W and Marable J H
CRITICAL PARAMETERS OF A PROTON-MODERATED AND PROTON-REFLECTED SLAB OF U^{235},
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (2 refs).

An attempt has been made to measure directly the minimum critical thickness of an infinitely high and infinitely wide hydrogen-reflected slab of aqueous solution of UO_2F_2 enriched to 93.2% in U^{235}. Extrapolation of the experimental results to infinite dimensions and correction for the container material yielded a value of 1.76 in. at a $H:U^{235}$ atomic ratio of 44. Oracle calculations for slabs which were critical in the experiment gave a value for k of 1.125. The calculated thickness of a slab for $k = 1$ was 1.38 in.

ORNL-2389-14

Maienschein F C, Peelle R W and Love T A
ENERGY SPECTRUM OF PROMPT GAMMA RAYS ACCOMPANYING THE FISSION OF U^{235},
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 12 pp. (14 refs).

Experiments are currently in progress at the BSF to measure the energy spectrum of prompt gamma rays accompanying U^{235} fission, by using the multiple-crystal scintillation spectrometer and a small spiral fission chamber. Coincidence circuits have been used to establish, by time-of-flight, that some of the observed pulses are neutron-induced. New shield configurations to protect the detectors from unwanted gamma rays or neutrons have been investigated, but not much improvement was found over the standard design. On completion of the quantitative determination of the neutron-induced background, the basic measurements will ensue.

ORNL-2389-15

Henry K M
U^{233} PROMPT-NEUTRON FISSION SPECTRUM,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp. (2 refs).

The large statistical errors of the previously reported U^{233} fission neutron spectrum were reduced by the use of a larger sample of material. The spectrum of a comparable mass of U^{235} is also reported. These "gray" samples produced a U^{233}/U^{235} yield ratio of 1.30 and a nearly identical spectrum.

ORNL-2389-16

deSaussure G and Silver E G
COMPARISON OF THE AVERAGE NUMBER OF PROMPT NEUTRONS EMITTED IN FISSION OF U^{233}, U^{235}, PU^{239}, AND PU^{241},
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 6pp. (8 refs).

The fast coincidence technique was employed to measure the relative prompt-neutron yields per fission of U^{233}, U^{235}, Pu^{239}, and Pu^{241} induced by thermal neutrons. The values obtained were $\nu^{23}/\nu^{25} = 1.02 \pm 0.01$, $\nu^{49}/\nu^{25} = 1.23 \pm 0.01$, and $\nu^{41}/\nu^{25} = 1.295 \pm 0.02$, where ν^{23}, ν^{25}, ν^{49}, and ν^{41} designate the prompt-neutron yields of U^{233}, U^{235}, Pu^{239}, and Pu^{241}, respectively.

ORNL-2389-17

deSaussure G and Silver E G
TIME-DEPENDENT NEUTRON DIFFUSION MEASUREMENTS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 12 pp. (23 refs).

An experiment is being designed to measure the diffusion properties of crystalline moderators at various temperatures by the pulsed-neutron-source method. The temperature effects will be most important in the regions in which crystalline effects cause sharp increases in the mean free paths (e.g., in Be, the increase from room temperature to $-100^{\circ}K$ is calculated to be about a factor of 10). The equipment for the experiment is being assembled. The pulsed-neutron source is being constructed at the BSF. The detector will be a very small $Li^{6}I(Eu)$ scintillator similar to others in use at the Laboratory. Time analysis will be obtained by an 18-channel system. The moderating assemblies of materials to be studied will be cubes of pure material, initially graphite or beryllium, which can be heated or cooled uniformly. The preliminary results which have been obtained, by means of another source, on beryllium and graphite agree satisfactorily with published results.

ORNL-2389-20

Dresner L
ANALYSIS OF LOW-ENERGY NEUTRON REACTIONS IN U^{238},
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 5 pp. (25 refs).

An analysis of experimental radiative capture and inelastic-scattering cross sections has been carried out with the statistical theory of reactions, appropriately modified to include fluctuations in the neutron widths. The analysis indicates that the p-wave strength function is slightly larger than the s-wave function.

ORNL-2389-21

Kuhn E and Dresner L
EFFECT OF FLUCTUATIONS IN THE REACTION WIDTHS ON RESONANCE INTEGRALS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp. (3 refs).

An estimate of the resonance capture integral of nonfissile nuclei, previously given, has been corrected to include the effect of fluctuation in the neutron width.

ORNL-2389-29

Goldstein H and Certaine J
SOME RECENT CALCULATIONS OF THE AGE OF FISSION NEUTRONS IN WATER,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp. (9 refs).

The discrepancy between the theoretical value of 26.0 ± 0.5 cm^2 and the experimental value of 30.0 ± 1.0 cm^2 for the age of fission neutrons in water is investigated. New data on the angular distribution ($\bar{\mu}$) of neutrons scattered by oxygen for the energy region below 2.7 Mev are used in a revised calculation. The new value was higher by only about 0.5 cm^2. Overestimates of corrections to this quantity above 2.7 Mev raise the calculated age to 28.0 cm^2. The effect on the age of several variations in the fission spectrum was also investigated, but no likely possibility is found to explain the basic discrepancy.

ORNL-2389-30

Marable J H
AGE OF FISSION NEUTRONS IN DIPHENYL AND IN OIL,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (1 ref).

The Oracle Monte Carlo neutron age code has been used to calculate the slowing down of fission neutrons past 1.45 ev in two organic compounds. The results were $47.51 \pm .5$ cm^2 for diphenyl ($C_{12}H_{10}$) and 22.75 ± 0.2 cm^2 for oil (essentially CH_2).

ORNL-2389-32

Cady D W and Warman E A
RADIATION ATTENUATION MEASUREMENTS IN PLAIN WATER, BORATED WATER, AND OIL MEDIA IN THE LTSF,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (12 refs).

The latest and best data are presented for attenuation from a fission source of fast-neutron dose, thermal-neutron flux, and gamma rays in water, borated water, and a saturated oil. The present thermal-neutron data are corrected for flux depression by the foil detectors, as well as for self-absorption and self-shielding of the detectors.

ORNL-2389-34

Miller J M
EFFECTIVE REMOVAL CROSS SECTION OF TUNGSTEN,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 1 p. (2 refs).

The effective removal cross section of tungsten has been determined as 3.13 ± 0.25 barns on the basis of thermal-neutron flux measurements made at the LTSF beyond a 4-in. thick sample of Hevimet (90 wt % tungsten, 6 wt % nickel, and 4 wt % copper). An earlier value of 2.51 ± 0.55 barns was determined from measurements beyond tungsten chips.

ORNL-2389-35

Watson F N, Davis R M and Champion W R
GAMMA-RAY AND THERMAL-NEUTRON MEASUREMENTS IN AIR AT VARIOUS DISTANCES FROM THE TOWER SHIELDING REACTOR,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 6 pp. (3 refs).

As a part of the continuing study of the air capture, scattering, and attenuation of reactor radiations, measurements have been made of the gamma-ray dose rate and thermal-neutron flux in air at various distances from the reactor at the TSF. Throughout these measurements, the reactor-detector height above the ground, their separation distance, the thickness of the reactor water shield, and the angle between the emitted reactor beam and the detector-reactor tank axis were varied. The results of the measurements are reported.

ORNL-2389-37

Muckenthaler F J, et al.
DETERMINATION OF GAMMA-RAY DOSE RATES AND SPECTRA FROM SOIL AND CONCRETE SAMPLES AFTER IRRADIATION AT THE TOWER SHIELDING FACILITY,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 6 pp.

One soil sample and concrete samples consisting of plain concrete, barytes concrete, and one sample of each containing an admixture of 1% boron were exposed for 20 hr to the TSR operating at 400 kev in order to determine how much they had been activated and which components were responsible. The dose rate at the positions of the concrete samples was 0.725 erg/g·hr·w, while that at the position of the soil sample was 0.896 erg/g·hr·w. Subsequent to irradiation, the intensity of the gamma-ray dose rate from the samples was determined as a function of time after irradiation. In addition, pulse-height spectra of gamma rays from the samples were determined. For the barytes and soil samples, a large part of the dose rate 4 hr after irradiation was due to a thermal (n,γ) reaction in Mn^{55}; between 24 and 100 hr after irradiation the main contribution was from the same reaction in Na^{23}. For the plain concrete samples,

the gamma-ray dose rate throughout the first 100 hr after irradiation was essentially due to the thermal (n, γ) reaction in Na^{23}.

ORNL-2389-45

Chapman G T and Love T A
TOTAL-ABSORPTION GAMMA-RAY SPECTROSCOPY,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 7 pp. (5 refs).

A very large, cylindrical NaI(Tl) crystal, 9-3/8 in. high, 9-3/8 in. in diameter, and truncated at one end, is being tried in a gamma-ray spectrometer. A large low-pulse-height tail in the response was attributed partly to a crystal defect and partly to difficulties of containing a gamma ray within the crystal after the first one or two scatterings. Drilling a hole 2 in. deep in one end and collimating the incoming radiation into the hole reduced the tail but worsened the resolution (width at half maximum) somewhat. The three photomultiplier tubes which were used had to be carefully matched in response to obtain best resolution. Work is continuing on improving the resolution, with an arrangement of seven small matched phototubes to be tried next.

ORNL-2389-46

Murray R B and Manning J J
FAST-NEUTRON SPECTROMETER DEVELOPMENT,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 9 pp. (5 refs).

Further investigation of $Li^6I(Eu)$ crystals indicate that they will be suitable for measuring fission-like neutron spectra above an energy of ~1.5 Mev.

ORNL-2389-47

Peelle R W and Love T A
PULSE-AMPLITUDE-INDEPENDENT TIMING CIRCUITS FOR DRIVING AN INTERMEDIATE-SPEED COINCIDENCE UNIT FROM THE OUTPUT OF A DOUBLE-LINE PULSE AMPLIFIER,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 11 pp. (5 refs).

Common types of coincidence circuitry for nuclear spectroscopy are reviewed briefly, and the properties of standard two-speed coincidence circuits are discussed. With the use of standard double-line-clipped linear pulse amplifiers, a property of the pulse shape permits the resolving time of the usual intermediate-speed coincidence system to be materially improved. Two novel circuits are described for taking advantage of this circumstance, and performance characteristics for one circuit are given in detail.

ORNL-2389-48

Kington J D and Abele R K
NEW ION CHAMBERS FOR GAMMA-RAY DOSE MEASUREMENTS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (1 ref).

A new, 50-cm^3 standard ion chamber has been built, in which the collection volume was made more nearly a spherical annulus than the previous standard composed of contiguous hemispherical and cylindrical annular regions. No improvement in uniformity of response with direction was observed. A 4-cm^3 ion chamber was also constructed for high-level measurements. Difficulties are being encountered in defining the collection volume. The leads may be responding also to the radiation field.

ORNL-2389-49

Peelle R W, Maienschein F C and Love T A
A SIMPLE TIME-TO-PULSE-HEIGHT CONVERTER FOR THE ANALYSIS OF TIME DIFFERENCES IN THE MILLIMICROSECOND RANGE,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 7 pp. (7 refs).

A method is described for modifying the sweep circuit of a standard laboratory oscilloscope to form the basic unit of a time-to-pulse-height converter. Combined with a standard multichannel pulse-height analyzer and standard timing circuitry, the unit is capable of performing with time resolution as fine as 2 to 3 mμsec/channel. Measurements on drift rate indicate that it is sufficiently small for such resolution to be feasible.

ORNL-2389-50

Muckenthaler F J
DEVELOPMENT OF THE HORNYAK BUTTON AS A FAST-NEUTRON DOSIMETER,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 9 pp. (3 refs).

Additional work has been done on the Hornyak button to find the crystal and particle size and composition that would most nearly duplicate the response of a Hurst-type fast-neutron dosimeter at various neutron energies. Previous data showed responses that were similar for neutron energies above 1 Mev but unsatisfactory for lower energies. New crystals were tested in an attempt to make the low-energy response as good as the high-energy response. The majority of the data was obtained with a monoenergetic neutron flux generated by the Van de Graaff generator. A limited number of crystals were also tested in the spectrum of neutrons from the TSF reactor.

ORNL-2389-51

Love T A, Maienschein F C and Peelle R W
AUTOMATIC COUNT-TIME CLOCK FOR USE WITH SLOW PULSE ANALYZERS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 1 p. (2 refs).

The variable, and relatively large, dead time per pulse of the 256-channel pulse-height analyzer designed at the Argonne National Laboratory leads to counting losses which are a function of the shape of the measured pulse-height spectrum as well as its magnitude. Hence, a device was built to meet the desired requirement of measuring the total time during which the analyzer will accept pulses rather than the elapsed time.

ORNL-2389-52

Goldman D T and Simon A
SPUTTERING PRODUCED BY IONS WITH ENERGIES ABOVE 50 KEV,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (3 refs).

Since the range of an incident particle having an energy in the region of 50 kev or higher is much greater than the mean free path of the knock-on particles produced through Rutherford collisions, it is justifiable to treat the primary particles as if they were produced by a uniform source in depth. Subsequent displacement of additional particles is accounted for and the problem is reduced to an equivalent one-velocity diffusion problem. Anisotropy of the primary source is also considered. The sputtering ratio is found to vary approximately inversely as $\ln E/E$, where E is the incident energy, as $\mu/(1+\mu)^2$, where μ is the ratio of the incident particle mass to the target particle mass, and as the secant of the incident angle.

ORNL-2480

Borkowski C J, (Director)
INSTRUMENTATION AND CONTROLS DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING JULY 1, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, July 29, 1958, 123 pp.

This report is a review of progress made by the Instrumentation and Controls Division at ORNL. The subject matter deals with specific instrumentation and controls for the various ORNL reactors along with such things as: (1) pickoff gates, (2) rate-meters, (3) spectrometers, (4) counters, and (5) instrumentation for the various specific divisions.

ORNL-CWS-2

Sheppard C W, et al.
X-RAY CALIBRATION IN THE BIOLOGY DIVISION OF OAK RIDGE NATIONAL LABORATORY,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, 28 pp. (7 refs).

This report covers the experience of the Biology Division in the use of their Victoreen ionization chambers and their efforts to standardize upon a method of calibration using a GE Maximar X-ray unit operating at 250 kvp. These chambers are used for X-ray dosimetry at Oak Ridge.

PD-121690 NP-5056(Del)(Vol. I)

Beaufait L J, Jr. and Lukens H R, Jr.
HANDBOOK OF RADIOCHEMICAL TECHNIQUES,
US Department of Commerce. Prepared by Western Division, Tracerlab, Inc., Berkeley, Calif., May 15, 1953, 141 pp.

This handbook has been prepared to systematize and correlate the information considered necessary for a precise radiochemical analysis of certain fission product and nonfission product activities. In making these precise radiochemical analyses, a number of steps are important; the principal ones are as follows:

1. The addition of accurately known amounts of carriers so that the gravimetric recovery of the activities may be obtained,

2. The ensuring of complete exchange of the carrier elements with their active isotopes,

3. The employment of a chemical procedure which gives purified (decontaminated) activities,

4. The precipitation of the activities as reproducible, standard compounds,

5. The mounting of these compounds in a uniform and reproducible manner,

6. The determination of the effect of precipitate thickness of the standard compounds on the counting efficiency of the radioactive isotopes.

In order to make precise comparative determinations of the resultant activities which may be related to absolute counting rates or atom ratios, several conditions must be maintained constant or their variance must be accurately known. The conditions that must be held constant are those involving the geometrical relationship between the sample and the counter tube. Those conditions whose variance must be accurately known and which are dependent on the detector in use include:

1. The coincidence correction,

2. The statistical behavior of the counting setup,

3. The intercomparison factor between the several counting setups, which is determined by the use of a standard source.

This handbook consists of two volumes covering the above points, and includes related information to aid in the determination of several fission products as well as of uranium, neptunium, and plutonium activities.

PR-0153-1

Graves Elizabeth R and Rosen Louis
DISTRIBUTION IN ENERGY OF THE NEUTRONS FROM THE INTERACTION OF 14-MEV NEUTRONS WITH SOME ELEMENTS,
Physical Review, Vol. 89, No. 2, pp. 343-348, January 15, 1953, (13 refs).

The neutron spectra from the interaction of 14-Mev neutrons with a number of elements have been determined by nuclear plate techniques. The plates were exposed to neutrons from the bombardment of a Zr-T target by 200-kev deuterons when the target was as nearly as possible isolated from all scattering material and when the target was surrounded by a spherical shell of the element to be investigated. The variation of $F(E_n)$, the number of emitted neutrons per unit energy interval with energy (E_n), appears to be Maxwellian in the region 0.5 to 4.0 Mev and may be represented by

$$F(E_n)dE_n = CE_n e^{-E_n/T} dE_n.$$

RDB(W)-TN

McLead D D
A FAST NEUTRON MONITOR
Department of Atomic Energy, Industrial Group, Windscale, England, January (1954), 7 pp. (2 refs).

The work described herein was initiated at the request of the R. & D. B. Health Physics section for a portable battery-operated fast neutron monitor for work in gamma fields up to about 0.7 R/hr (60 mpl). The monitor should be insensitive to slow neutrons.

Previous work on such detectors suggested that, for good discrimination against a gamma background, the use of either a polythene-coated counter or one with a methane filling would be advantageous. For reasons of simplicity, experiments were carried out on the latter.

REIC-6 AD-157172

Oestmann M J, Kircher J F and Schall P J
A SURVEY OF CURRENT RESEARCH AND DEVELOPMENTS IN THE FIELD OF DOSIMETRY,
Battelle Memorial Institute, Columbus, Ohio, Contract No. AF33(616)-5171, May 31, 1958, 38 pp. (132 refs).

A survey of current practices used in high-level dosimetry of gamma, neutron, and mixed fields is presented. Chemical and colorimetric systems including ferrous-ferric, ceric-cerous, gas evolution, nitrous oxide, various dyes, and polymers have been considered. Silver-activated phosphate and other glasses are discussed. Ionization chambers for either gamma ray or neutron measurements have been commonly employed at very high dose rates and several designs are discussed.

Luminors, such as anthracene and napthalene, and semiconductors, such as germanium, have also found application at high radiation doses. Different designs of calorimeters have been used for measuring energy absorbed, but only to a limited extent.

Neutron spectra ranging from thermal through resonance to fast neutrons can best be determined by activation of appropriate materials having desirable nuclear properties. An extensive bibliography is provided for those interested in further details on any particular system.

REIC-6 (Add 1) AD-210766

Oestmann Mary J and Kircher J F
A SURVEY OF CURRENT RESEARCH AND DEVELOPMENTS IN THE FIELD OF DOSIMETRY,
The Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio, March 31, 1959, 16 pp. (40 refs).

This is the first addendum to the REIC Report No. 6 "A Survey of Current Research and Developments in the Field of Dosimetry". Very few new dosimeter concepts have been reported during the past year. Advances made during 1958 consist primarily of refinements of the previously established dosimeter systems. Investigations have involved reaction mechanisms and the determination of more accurate G-values. An

appropriate choice of materials has helped to extend the useful range of some dosimeters. Standard foils and methods of measurement of these foils are being developed for neutron dosimetry. Further details on any one system may be found from the extensive bibliography provided.

REPF-100

THEORETICAL POSSIBILITIES AND CONSEQUENCES OF MAJOR ACCIDENTS IN LARGE NUCLEAR POWER PLANTS,
USAEC, Washington, D.C., (1957), 187 pp.

This report is a study of possible consequences if certain assumed accidents, theoretically possible but highly improbable, were to occur in large nuclear power plants. The probability of a catastrophic reactor accident is quite low based on a limited history of reactor operation and certain assumptions based on general knowledge of reactor operation. Damage studies and consequences of the assumed reactor accidents are based on the following listed studies:

1. The nature and extent of a fission product release from a power reactor,
2. Description of reactor and site,
3. Fission product activity in the 500,000-tkw reactor,
4. Effects of fission products release on humans and land use,
5. Diffusion, deposition, and rainout of the radioactive cloud,
6. A method for calculating the number of people that could be affected by a fission product release,
7. Basic assumptions in calculating potential losses,
8. Consequences of gamma radiation from a 100% release of the fission products into the containment shell,
9. Personal and property damage resulting from release of fission products from a 500,000 kw (thermal reactor).

REPF-104

Hurst G S, Ritchie R H and Mills W A
FAST NEUTRON DOSIMETRY,
Paper-65 given at the first Geneva Conference, August (1955), 20 pp. (15 refs).

This paper discusses three methods of measuring the tissue dose due to fast neutrons. These methods were developed at the Oak Ridge National Laboratory. All three methods have yielded practical instruments capable of accurately measuring a fast neutron dose even if a gamma dose rate much greater than the neutron dose rate is present. These three methods are: (1) proportional counter, (2) threshold detector, and (3) count rate dosimeters.

SCEL-TM-M-1917 AD-149957

Murphy H M, Jr.
NEUTRON DOSIMETRY AT U.S. ARMY SIGNAL ENGINEERING LABORATORIES,
Fort Monmouth, New Jersey, November 1, 1957, 27 pp. (37 refs).

This report discusses briefly the history, theory, and current state of the neutron dosimetry work being done in the Evans Signal Laboratory. Specific types of dosimetry systems are discussed, i.e., hydrocarbon dye, ionization chambers, and tissue-equivalent plastic. Two USASEL experimental dosimeters of the ionization chamber type are discussed.

SCTM-93-56-(16)

Milton Osborne
AN AUDIBLE RADIATION DOSIMETER,
Sandia Corporation, Albuquerque, N. M., May 7, 1956, 18 pp. (3 refs).

An instrument is described which integrates gamma radiation flux and sounds an audible warning when a preset dose has accumulated.

SCTM-131-58-(16)

Cropper W H
A THEORY OF THE RADIATION CHEMISTRY OF SOLUTIONS,
Sandia Corporation, Albuquerque, N.M., Contract No. AT-(29-1)-789, April 22, 1958, 52 pp. (21 refs).

A general discussion of the radiation chemistry of solutions is given. A theory is developed, based on a kinetic analysis of a general radical attack reaction scheme. Fundamental equations are obtained and a calculation technique is described. The results are found to be in agreement with all aspects of solution radiation chemistry. The following special applications are discussed: (a) effects at high doses, (b) effects at low doses, (c) effects at high solute concentrations, (d) effects at low solute concentrations, and (e) the general effects in nonaqueous solvents.

SCTM-250-59-(51)

Truby F K
A PROGRAM FOR THE STUDY OF FREE RADICAL ACCEPTOR MECHANISMS,
Sandia Corporation, Albuquerque, N.M., July 20, 1959, 9 pp.

A research program is presented covering the study of the mechanisms involved in free radical acceptor reactions. These reactions tend to minimize damage produced in pertinent materials while being subjected to ionizing radiation. The study will be confined to those free radical acceptor systems which effect protection through single electron transfer processes. The program will utilize electron paramagnetic resonance techniques to study the free reactions involved. Typical of the systems to be studied will be those containing the disulfide link.

SD-2075

Bailey L Evan and Kelly R L
RADIATION EFFECTS STUDIES,
Stanford Research Institute, Menlo Park, Calif., February 12, 1958, 36 pp. (references).

A program of radiation effects studies was set up for Sandia Corporation for the purpose of providing some preliminary data on a number of materials of interest, and to give the Sandia staff experience in techniques for such investigations which they will later be carrying out at Sandia.

This program consisted of work in several categories, which were specified in a series of task order letters:

I. Neutron flux and dose measurement techniques,

II. Semiconductor measurement techniques and study of irradiation effects of neutrons on semiconductors,

III. Effects of neutrons and electrons on alkali-halide crystals,

IV. Study of electron and gamma-ray effects on polymers, and techniques of measurement,

V. Experiment on effect of pulsed ionizing radiation on spark gaps.

This report covers the work done under Tasks I and II. The tasks are summarized below:

Task I.-- Methods of neutron flux and dose measurement were compared to evaluate their applicability to small sample studies in the inhomogeneous neutron flux close to a neutron source. Comparisons are made of BF_3 counters, activated foils, and photographic emulsions. It is concluded that activated foils are most precise, but that photographic emulsion measurements can provide rough data at very low cost. Counters are not very satisfactory for this type of monitoring because of their relatively large dimensions. Theory and references are given for the various neutron counting techniques.

Task II.-- Methods were developed for preparation of samples of single crystals of germanium and silicon. Measurements of resistivity, magnetoresistance, Hall effect, and carrier lifetime were made on various samples before and after exposure to various doses of fast neutrons, deuterons, and electrons. Changes in resistivity and mobility of germanium samples were found for electron and neutron irradiation. Measurements of minority carrier lifetime were made. The values obtained were found to depend on many factors, not all of which were identified.

SIGFM/EL-SX-1058

Kronenberg Stanley and Murphy Harry M, Jr.
EVALUATION OF SEMIRAD FOR DOSE-RATE-INDEPENDENT MEASUREMENT OF FAST-NEUTRON AND GAMMA RADIATIONS,
US Army Signal Research and Development Laboratory, Exploratory Research Division S, Surveillance Department, Evans Area, Belmar, N.J., October 10, 1958, 39 pp. (11 refs).

This report describes the principles of secondary-electron mixed-radiation dosimeter (SEMIRAD) operation, and discusses results of experiments performed at USASRDL, the Los Alamos Scientific Laboratory Godiva II facility, and the Naval Research Laboratory. The purpose of this report is: (1) to make a preliminary evaluation of SEMIRAD based on theoretical computation and experiments conducted to date, and (2) to propose a program for future research work on SEMIRAD.

Description of SEMIRAD. -- In general construction, SEMIRAD has the same appearance as ion chambers. However, instead of being filled with air or other gas, SEMIRAD is evacuated to a very low pressure. As a consequence, little or no ionization is produced in SEMIRAD, and the entire response is due to secondary-electron production.

When the wall of a SEMIRAD detecting chamber is irradiated with X-rays, gamma rays, or neutrons, a number of particles are ejected from the wall. In the case of X- and gamma rays, these particles are photo-electrons of 50 to 100 kev energy and Compton electrons of a few hundred to a thousand-kev energy. For very high-energy gammas these particles include both positrons and electrons from pair production. In the case of fast neutrons, the ejected particles are mainly protons (hydrogen nuclei) of energy averaging one-half that of the neutrons. When these ejected particles pass through the surface of the wall of the SEMIRAD chamber, they cause secondary emission of low-energy electrons. Secondary electrons are also emitted when the high-energy Compton and photoelectrons or protons re-enter the opposite wall of the chamber. If a positively charged electrode is placed within the chamber, the low-energy secondary electrons are easily swept up, and the total charge collected is proportional to the radiation dose received.

SIGFM/EL-SXR-1258-1

Murphy Harry M, Jr.
RADIATION MEASUREMENTS AT GODIVA II,
Army Signal Corps, Exploratory Research Division S, Surveillance Department, Evans Area, Belmar, N.J., December 17, 1958.

This memo describes a number of radiation measuring techniques and summarizes their results for Godiva II radiation burst measurements. The need for further work in this field is pointed out. In particular, the exact gamma-ray contribution to the prompt radiation dose is only very roughly known, and the gamma dose from the fission product activity is also only poorly known.

Fast neutron total dose measurements were made using 5 gram, 1-inch diameter compressed sulphur pellets. The sulphur neutron dose (n/cm^2 over 2.5 Mev) is given as a function of distance (from 10 to 500 cm from center of the assembly) for a standard burst of 10^{16} fissions, and is shown to approximate the inverse square law.

Thermal-neutron total dose measurements were made using gold and gold-cadmium activation foils. These measurements have shown that the thermal-neutron flux (n/cm^2 over 0.5 ev) does not follow the inverse square law, but remains relatively constant at a value of about 4×10^9 n/cm^2 for a standard burst within about 2 meters of the assembly.

Gamma total dose measurements were made using NBS (Evans) photographic dosimeters (containing DuPont photographic emulsions 502, 834 and 1290). Calibration films exposed to Co^{60} gamma radiation were developed simultaneously with films exposed at Godiva II. The gamma dose is given as a function of distance (from 60 cm from center of the assembly) for a standard burst of 10^{16} fissions, and corresponds to about 8% of the corresponding neutron dose expressed in rads. The gamma dose received from fission product activity is apparently no more than about 10% of the total gamma dose.

SEMIRAD (secondary-electron mixed radiation dosimeter) measurements of neutron dose rate produced a curve probably representing a typical Godiva burst. The width of the pulse at half-height was about 90 microseconds, and the peak of the delivery rate occurred at about 180 microseconds after the reactor "scram" trigger pulse. SEMIRAD measurements of the gamma dose rate indicated that the prompt gamma pulse from Godiva II is proportional to the neutron pulse, and that the gamma dose rate during the burst is roughly 10% of the neutron dose rate (both radiations expressed in rads). SEMIRAD measurements are considered tentative since the principle involved is still under study by USASRDL.

SIGFM/EL-SX-1258-2

Kronenberg Stanley and Murphy Harry M
GODIVA II IRRADIATION OF SEMIRAD, 9 AND 10 OCTOBER 1958,
US Army Signal Research and Development Laboratory, Exploratory Research Divisions, Surveillance Department, Evans Area, Belmar, N. J., December 17, 1958, 18 pp. (4 refs).

This report describes an experiment in which SEMIRAD (secondary-electron mixed-radiation dosimeter) was exposed to the Godiva II radiation burst. The purpose of this experiment was: (1) to test the capabilities of SEMIRAD for measurement of ultrahigh radiation intensities with short resolving times at the highest possible neutron radiation dose rates obtainable under laboratory conditions, and (2) to measure the relative spread in time of the neutron delivery rate due to time-of-flight and scattering effects at a distance corresponding to approximately one-third mean free path from Godiva II.

The results of this experiment were obtained from photographs of triggered oscilloscope traces of the SEMIRAD response to each Godiva II burst. The results so obtained were transformed to yield dose rate as a function of time by comparing the integral of the traces with the total fast neutron dose received by the SEMIRAD as measured by sulphur pellets.

SEMIRAD of the diode-type measured dose rates as high as 1×10^{12} rads per hour without any detectable dose-rate dependence, and with completely satisfactory time resolution. Since this SEMIRAD type is, according to the Langmuir formula, of very poor geometry, it is concluded tentatively that with better geometry SEMIRAD should be capable of several orders of magnitude improvement in dose-rate measuring ability.

Results from the SEMIRAD positioned approximately 100 meters from the Godiva II showed that the dose rate a few feet above the earth at that distance is spread in time over 900 microseconds. It is believed that this time spread is only slightly the result of time-of-flight effects, and is probably the result of scattering and neutron energy degradation.

TID-375

Shannon Robert L
RADIOACTIVE WASTE DISPOSAL - A BIBLIOGRAPHY OF UNCLASSIFIED LITERATURE,
USAEC Technical Information Division, Oak Ridge, Tenn., August (1950), 8 pp.

This bibliography of unclassified references to radioactive waste disposal was compiled in response to a specific request. It is a highly selected bibliography and does not attempt to cover all references to the subject.

Although most of the work on this problem is classified, much information of a general, practical, and specific nature has been released.

The purpose of the bibliography is to provide a source of information on various processes and methods of radioactive waste disposal. These methods can be categorized as follows:

1. Dilution and release into sewage systems and waterways where bacterial action eliminates radioactivity hazards,
2. Neutralization before release into sewage systems,
3. Concentration and storage,
4. Incineration,
5. Dilution of radioactive gases into the atmosphere.

References to laboratory equipment other than waste disposal systems are incidental.

TID-5057

Sailor V L
DETERMINATION OF CENTRAL FLUX WITH INDIUM FOILS,
Brookhaven National Laboratory, Upton, N.Y., February 6, 1951, 2 pp.

A method is given whereby an activated indium foil is used to measure flux. The chemical procedure as well as sample calculations and some estimate of the sources of error indicate this method to be the equal of the most precise method known. The subcritical indium foil measurement.

TID-5300

Way K
NUCLEAR LEVEL SCHEMES,
National Academy of Sciences, National Research Council, Washington, D.C., September (1955), 221 pp. (20 refs).

A collection of diagrams showing positions and properties of nuclear energy levels, characteristics of radioactive decay and nuclear reactions, together with a tabular compilation of the experimental data and bibliographic references to the original papers.

TID-8006

Schulman James H
GLASS DOSIMETERS FOR RADIATION MEASUREMENT,
US Naval Research Laboratory, Washington, D.C., March (1956), 17 pp.

The impact of nuclear energy on technology, both in peace and in war, has broadened the need for radiation measuring devices, which were once of concern only to a few specialized physical and clinical laboratories. Today the measurement of radiation dose is important not only to the radiologist but to many others as well. The food technologist, interested in the possible pasteurization or sterilization of foods by radiation, is concerned with measuring doses of gamma rays in the range of 10,000 to 10,000,000 roentgens. The plastics technologist, interested in the present plastics

by radiation-induced cross-linking, is likewise concerned with measuring massive doses of gamma rays and high energy electron beams. And in this age of nuclear weapons, simple devices for measuring dangerous radiations in the range of 10 to 600 roentgens are of extreme importance to the armed services and even to the private citizen.

The purpose of this article is to describe some new methods of dosimetry applicable to the above-mentioned problems of radiation measurement and to describe also the devices embodying the use of these methods. These developments in the practice of radiation measurement are the by-products of basic research at the US Naval Research Laboratory on the luminescence and coloration of solids.

TID-8009

Graham Richard H and Boyer D Glenn
AEC EXPERIMENTAL PROGRAM ON REACTOR SAFETY,
Industrial Information Branch, USAEC Technical Information Service, Washington 25, D.C., February (1956), 6 pp.

Brief discussions are given concerning the five reactor concepts of a heterogeneous test facility, SPERT (Special Power Excursion Reactor Test), at the National Reactor Testing Station in Idaho and the three proposals of a small homogeneous test facility, KEWB (Kinetic Experiments on Water Boilers), at North American Aviation, Inc., Santa Susana, California. Brief summaries are also presented on the research objectives and statuses of fuse development, molten metal-water reactions, container tests, and fuel ignition studies.

TL-CML-2562-FR/52

Berstein Irving A, et al.
CHEMICAL SYSTEMS SENSITIVE TO RADIATION,
Final Report, July 1, 1951 - June 30, 1952, Tracerlab, Inc., Boston, Mass., Contract No. DA-18-108-CML-2562, (1952), 16 pp. (references).

This report deals with the development of a chemical system sensitive to gamma radiation over the dosage range 0-600R that would be suitable for large scale production of a direct-reading dosimeter. To be acceptable, the device should be capable of being inexpensively produced and should give a reliable reading that is independent of variations of temperature conditions in the field and in storage.

During the course of the contract, several different types of chemical systems have been investigated. The basis of choice of all the systems studied is that in each one there exists an inherent "magnification factor," either an actual chain reaction leading to a large number of reacted molecules per radical formed under radiation or an "apparent" multiplication such as a large color change for a small amount of radiation product.

Dosimeters prepared from two of the systems investigated--aqueous acrylonitrile dosimeter and the bulk acrylonitrile dosimeter--have been tested in the field. The aqueous acrylonitrile system was about ten times less sensitive in the field as in the laboratory. However, a preliminary report on the response of the bulk acrylonitrile dosimeters indicated that these dosimeters were of the same order of sensitivity in the field as in the laboratory. Readily detectable changes occur after exposure to 35-50R of Co^{60} gamma radiation. The heat stability of this system is remarkable for a monomer,

as "oxygen-free" acrylonitrile has been heated at 55°C for 3-1/2 weeks with no visible change. A reliable and convenient packaging procedure has been developed for the preparation of "oxygen-free" dosimeters.

TL-CML-2562-FR/53

Berstein Irving A, et al.
CHEMICAL SYSTEMS SENSITIVE TO RADIATION,
Final Report, July 1, 1952 - February 28, 1953, Tracerlab, Inc., Boston, Mass.,
Contract No. DA-18-108-CML-2562, (1953), 16 pp. (18 refs).

This report summarizes work performed during the period from July 1, 1952 to February 28, 1953 on the development of chemical systems sensitive to radiation for use as direct-reading dosimeters.

During this time, three systems have been investigated:

1. Several types of halogenated plastics containing pH indicators were prepared and exposed to gamma radiation.
2. The gamma radiation induced polymerization of acrylonitrile was investigated and the results indicated the system to be promising as a "contamination area" dosimeter.
3. A system of carbon tetrachloride-benzene-indicator-dimethyl aniline has been investigated for use as a tactical dosimeter.

TL-CML-2562-MR-6 AT1-150-188

Fields Melvin (Director)
CHEMICAL SYSTEMS SENSITIVE TO RADIATION,
Monthly Report No. 6, December 1-31, 1952, Tracerlab, Inc., Boston, Mass.,
Contract No. DA-18-108-CML-2562, December (1951), 15 pp.

During the last month, work on the aqueous monomer solutions has been directed toward increasing the radiation sensitivity, desensitizing the system to respond to doses up to 600 R, and continuing tests of the effects of heat and light on the radiation sensitivity. Attempts to increase the sensitivity of the system by using an acid solution of pH - 1 and by addition of methanol have indicated no significant increase in radiation sensitivity.

Efforts to desensitize the system by employing more dilute solutions of acrylonitrile have been unsatisfactory. Experiments are underway to attempt to decrease the radiation sensitivity in clear-cut increments by the addition of potent radical inhibitors to the system. Tests on the stability to heat and light of the acrylonitrile-water solution are encouraging. Samples exposed to light and heat at 80°C for 20 days having exhibited no apparent change in radiation sensitivity.

A procedure has been developed for the preparation of halogenated plastic masses containing pH indicators by polymerization of oxygen-free solutions of halogenated compound and a monomer. Several combinations of halogenated compound and monomer have been found that yield clear, hard plastic masses on polymerization. Several plastics prepared from a mixture of monomer and a commercial vinyl chloride-vinylidene chloride resin on exposure to Co^{60} gamma radiation have evidenced a

visible change after exposure to several thousand roentgens and a period of standing of two to three weeks. The spectral characteristics of three irradiated plastics have been determined spectrophotometrically, and limited data clearly point to significant changes in the irradiated samples on standing.

TL-CML-2562-MR-20 AD-6512

Berstein Irving A, et al.
CHEMICAL SYSTEMS SENSITIVE TO RADIATION,
Monthly Report No. 20, February 1953, Tracerlab, Inc., Boston, Mass., Contract No. DA-18-108-CML-2562, February 28, 1953, 9 pp.

Fifty colorimetric tactical dosimeters based on the carbon tetrachloride-benzene-indicator-sensitizer systems were submitted to the Army Chemical Center for field tests. A complete description of the composition of the solutions and the assembly procedure is reported. A sketch of the dosimeter is drawn to scale. Sample color standards used for reading the dosimeters are included. Studies that should be made to evaluate and improve this system are listed.

Nine acrylonitrile "contamination-area" dosimeters were submitted to the Army Chemical Center for field tests. The method of preparation of the dosimeters and instructions for reading the dosimeters are described. A sketch of the dosimeter is included.

Factors that should be investigated to determine the utility of the acrylonitrile dosimeter are listed.

TM-58-66 X-24535

SIXTH MEETING OF THE ANP ADVISORY COMMITTEE FOR NUCLEAR MEASUREMENTS AND STANDARDS,
Materials Laboratory, Wright Air Development Center, Wright-Patterson AFB, Ohio, April 7, 1958, 35 pp.

The following conclusions were arrived at as a result of this meeting:

1. Two basic problems are still unsolved. These are:
   a. Correlation of fast neutron effects on materials in reactor environments;
   b. Correlation of gamma-ray effects on materials in mixed neutron-gamma ray fields.

Further analysis is needed before the Committee will be able to reach any definite conclusions in these areas.

2. The graphite ion chamber looks promising for gamma-ray measurements in mixed fields; however, more work is needed in defining its capabilities and limitations and in proving out various designs.

3. Threshold foil measurements should still be used for neutron measurements; however, standard techniques have not been worked out yet. There is a strong need for standard foils and well-defined techniques for utilizing them.

4. More work should be done on correlating radiation damage in neutron environments. The conflict between "Hydrogen Dose" and the information presented by Dr. Primak should be analyzed and resolved.

5. The Materials Laboratory will work on the above problems and prepare recommendations for the Committee's consideration. These recommendations will be forwarded to Committee members in advance of a meeting to allow time for study.

6. Information meetings on "state of the art" developments in nuclear instrumentation and techniques are valuable and should perhaps be sponsored once a year.

7. The frequency of meetings should depend upon Air Force requirements and the importance of the problems to be considered. Since considerable analytical and experimental work must be done on Committee recommendations, a meeting once or twice a year may now be sufficient.

UCLA-304

Taplin George V
APPLICABILITY OF CHEMICAL DOSIMETRY IN CIVIL DEFENSE,
University of California at Los Angeles, Los Angeles, Calif., Contract No. AT-(04-1)-Gen-12, September 15, 1954, 26 pp. (6 refs).

The radiation characteristics of two types of chemical systems utilizing chlorinated hydrocarbons and aqueous pH indicator dyes are described. The report includes both laboratory and field test data which demonstrate the practical applicability of chemical systems in measuring prompt and/or residual bomb gamma radiation, as well as fast neutron radiation in the biologically interesting dosage range (50 to 600 r).

UCLA-309

Warren Stafford L
INITIAL DEVELOPMENT OF A SEMI-CONDUCTOR FAST NEUTRON DOSIMETER,
University of California at Los Angeles, Calif., Contract No. AT-(04-1)-Gen-12, October 15, 1954, 15 pp. (1 ref).

The current methods of construction and measurement of single crystal germanium fast neutron dosimeters are described. The results of preliminary calibration attempts indicate that the conductivity change of these dosimeters responds linearly from 200 rep to at least 4800 rep of cyclotron-produced neutrons having a spectrum resembling a fission spectrum. At 100 rep the conductivity decreases very slightly instead of increasing. This effect probably arises from going over the hump from slightly n-type to slightly p-type germanium. It is being tested as to whether a preirradiation will enable linearity to be obtained in the 100 rep range or less. In any event, a biologically interesting range of fast neutron dosages can be studied with these dosimeters, even in the presence of much larger rep dosages of gamma radiation.

UCRL-4266

Benveniste Jack and Zenger Jerry
INFORMATION ON THE NEUTRONS PRODUCED IN THE H^3(d, n)-He^4 REACTION,
University of California Radiation Laboratory, Livermore, Calif., Contract No. W-7405-Eng-48, January (1954), 31 pp. (9 refs).

This compilation of tables and graphs of the more important kinematical relations describing the D-T reaction is intended for the reference of experimenters working with the Cockroft-Walton Accelerator.

UCRL-5375

Gunn Stuart R
HIGH-CAPACITY RADIOMETRIC CALORIMETERS,
University of California Radiation Laboratory, Livermore, Calif., Contract No. W-7405-Eng-48, November 13, 1958, 17 pp.

Calorimeters of the steady-state conduction type and flow type for precise determination of powers of radioactive samples from about 3 to 20 watts are described. One of the calorimeters is used under water to provide radiation shielding.

Results of comparative measurements with these and other calorimeters at this laboratory and at the Mound Laboratory are given.

UCRL-5420

Howerton Robert J
THE STATUS OF EXPERIMENTAL NEUTRON CROSS SECTIONS FOR ENERGIES BETWEEN 0.5 AND 14.5 MEV,
Lawrence Radiation Laboratory, Livermore, Calif., Contract No. W-7405-Eng-48, December (1958), 26 pp. (references).

The present state of knowledge of the total, elastic scattering, inelastic scattering and (n, 2n) cross sections from 0.5 to 14.5 Mev is presented, and it is such that at least nine years of measurement at the rate of the most productive year to date would be required to eliminate, by experiment, the ignorance (lack of data) of these values. It is estimated that, with good fortune in developing systematics and mathematical models, all the problems of neutron cross sections in this energy range may be solved in 20 years if an effort is concentrated equal to that expended in the most productive year to date.

UR-167

Kanwisher John W
A CHEMICAL DOSIMETER FOR IONIZING RADIATIONS,
University of Rochester, Rochester 20, N.Y., Contract No. W-7401-Eng-49, August 29, 1951, 62 pp. (10 refs).

This paper discusses the development of a method for measuring dosage of penetrating ionizing radiation, namely, X- and γ-rays. The method is based on measuring the chemical change produced by the radiation in a two-phase system of chloroform and water. The end result of the radiation is the production of small amounts of hydrochloric acid. This selectively enters the water phase and changes its conductivity. The conductivity is measured by determining the absorption of energy from a radio-frequency field by the water phase. The present dosimeter, which is intended for casualty use, has a full-scale range of 600 roentgens. A full-scale range of 100 roentgens is entirely possible. In the other direction the dosimeter can be made as insensitive as desired.

UR-381

Baum J W
NEUTRON DOSIMETRY - A REVIEW,
University of Rochester, Rochester, N.Y., Contract No. W-7401-Eng-49, March 29, 1955, 116 pp. (189 refs).

This review summarizes information on the following subjects: (1) physical processes of importance in neutron dosimetry, (2) biological effects of neutrons, (3) neutron sources, and (4) instruments and methods used in neutron dosimetry. Also, possible improvements in dosimetry instrumentation are outlined and discussed.

USNRDL-TR-224

Ross S W and Tochilin E
A SIMPLIFIED FILM DOSIMETER FOR FISSION NEUTRONS,
US Naval Radiological Defense Laboratory, San Francisco 24, Calif., April 5, 1958, 23 pp. (19 refs).

A film dosimeter technique has been developed for fast neutron monitoring of reactor personnel. The method takes advantage of the rapid build-up of thermal neutrons when fast neutrons are allowed to penetrate a hydrogeneous moderator. The badge consists of a 3/4-inch thick polyethylene frontpiece that is worn on the belt against the body. A combination of silver and tin filters are matched so as to produce equal film blackening from either X- or gamma rays. Fast neutron exposure is determined from film blackening under radioactive silver produced by capture of the moderated neutrons. The badge contains a sensitive gamma-ray dosimeter film together with a nuclear track emulsion. The dosimeter film serves as both a fast neutron and gamma-ray dosimeter. The nuclear emulsion is read whenever an overexposure is indicated or under any other condition where a more accurate evaluation of the fast neutron dose is warranted.

WADC-TN-56-196 AD-103231

Tillotson J H, Lt. and Srp N E
GAMMA DOSIMETRY PROPERTIES OF LINEAR POLYETHYLENE BY INFRARED ANALYSIS,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, May (1956), 12 pp. (7 refs).

Changes in the molecular structure of long chain polymers by infrared analysis give an indication of damage to material after its exposure to nuclear radiations. The intensity changes of the 5.8 and 11.0 micron infrared absorption bands in gamma-irradiated Marlex 50, a high density linear polyethylene, are analyzed and presented as a measure of relative gamma dosimetry. All radiation exposures were conducted at the National Reactor Test Station, Idaho Falls, Idaho. The infrared absorption spectra were recorded at the Wright Air Development Center using a Baird double-beam recording spectrophotometer. The graphs of optical density versus gamma dosage are believed to represent in a realistic manner the gamma dosimetry properties of the polyethylene used in this investigation.

WADC-TN-57-298

Brocklehurst Robert E (Secretary)
PROCEEDINGS OF THE ANP SPECTROSCOPY INFORMATION MEETING HELD AUGUST 6-7, 1957,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, February (1958), 224 pp. (references)

This report is a compilation of the unclassified papers given at the ANP Spectroscopy Information Meeting held at Wright-Patterson Air Force Base, August 6 and 7, 1957. The subjects covered in these proceedings are instrumentation for gamma and neutron spectral measurements, treatment of experimental data, characteristics of scintillation crystals, and the use of beam collimators.

WADC-TN-57-298 (Pt. 1) AD-142342

Newacheck R L and Randall J D
DEVELOPMENT OF THRESHOLD FOILS FOR NEUTRON SPECTRA DETERMINATION,
Wright Air Development Center, ANP Advisory Committee for Nuclear Measurement and Standards, February (1958).

This paper describes the techniques that will be used to develop and standardize a series of neutron-sensitive foils that may be used to obtain approximate neutron spectra for radiation-damage studies. A method of calibrating the foils with a low-flux research reactor is discussed. Tentative designs are presented for U^{238}, S^{32}, and boron-covered Pu^{239} threshold foils that will be used to measure fast-neutron spectra.

WADC-TN-57-335 AD-142249

Hickmott Robert L
FEASIBILITY OF A GRAPHITE-CARBON DIOXIDE IONIZATION CHAMBER TO MEASURE CARBON DOSE AT HIGH DOSE RATES,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December (1957).

This report discusses the feasibility of designing a graphite-carbon dioxide ion chamber for the absolute measurement of the carbon dose rate from a pure gamma field up to 10^{10} erg/g/hr. There are insufficient data on neutron response to judge the feasibility of using an ion chamber in mixed fields with large neutron components.

WADC-TR-56-548 AD-118062

Burke Edward A, 1/Lt. (USAF)
MEASUREMENT OF RADON GAS IN CYLINDRICAL IONIZATION CHAMBERS,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, May (1957), 6 pp. (4 refs).

Three of the fundamental problems encountered in the measurement of radon gas using cylindrical ionization chambers are discussed and solutions presented. These are: variation of ionization current with short half-life radon daughters, effect of dielectric absorption, and calibration of the ionization chamber.

WADC-TR-56-657

Hartmann Sven R, 1/Lt. (USAF)
THEORETICAL ANALYSIS OF THE RESPONSE OF A PROTON RECOIL TYPE NEUTRON DETECTOR,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, May (1957), 48 pp.

A calculation is made to determine the number of recoil protons produced per unit area, by a neutron flux of arbitrary energy, in an infinite hydrogenous slab which reaches but does not pass through an infinite detector slab located immediately behind a hydrogenous slab. A general case is considered for an isotropic neutron flux incident upon the above system in which an arbitrary thickness of some proton absorbing material separates the hydrogenous and detector slabs. A discussion of the results is given indicating how one can control the energy and the energy interval over which the system is sensitive to neutrons. A final calculation is made to determine the response of the system to a collimated neutron flux for an arbitrary orientation of the hydrogenous-detector system. This is done so that the effect of a nonisotropic flux can be determined.

WADC-TR-57-3

Uthe Paul M Jr.
ATTAINMENT OF NEUTRON FLUX-SPECTRA FROM FOIL ACTIVATIONS,
Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, March (1957), 84 pp.

Several analytical methods are described for obtaining neutron flux-spectra knowledge from foil data. The response functions used are the nuclear reaction characteristics of threshold, fast fission, and resonance-type foils.

Two previously used methods and two new methods are discussed. The previously used methods are the Trice Method and the Cadmium Difference Method. The Trice Method, applicable in the fast neutron energy region, uses a "step function" cross-section representation. The step function energy threshold is determined by assuming a differential flux function. The Cadmium Difference Method, applicable in the 1/E energy region, uses the resonance activation integrals of resonance-type foils as cross-section parameters. Although consideration is given to these methods, major interest is focused on two new methods. These methods are called the Polygonal Method and the Polynomial Method.

The Polygonal Method uses the cross sections in their true form and represents the flux-energy spectrum by a combination of linear functions of energy. In performing the necessary calculations, difficulty in selecting certain energy parameters is experienced.

The Polynomial Method uses the cross sections in their true form and represents the flux-energy spectrum by a weighting function times a polynomial. The degree of the polynomial is one less than the number of different foils used. A digital computer is conveniently used for the required numerical calculations.

The result of several test cases using the Polynomial Method indicates that considerable improvement over the Trice Method is achieved.

WA-OMRO-13A-A5

Wright David U Jr.
ANALYSIS OF ACTIVATED SPECTROSCOPIC COPPER,
Aberdeen Proving Ground. Presented at conference on Effects of Nuclear Radiations on Materials, Watertown Arsenal, Watertown 72, Mass., October 1-2, 1957, 3 pp. (2 refs).

Samples of spectroscopic grade copper were irradiated at Brookhaven National Laboratory for one week. The results of the extended irradiation were recorded sometime later, at 12 and 20 months, with a single-channel gamma spectrometer. The recorded spectra are not that due to irradiated Cu-63 and Cu-64 alone but, for the most part, due to the impurities in spectroscopic copper.

WA-OMRO-13A-A6

Wright David U Jr.
ANALYSIS OF ACTIVATED BLAST GAGE COMPONENTS,
Aberdeen Proving Ground. Presented at conference on Effects of Nuclear Radiations on Materials, Watertown Arsenal, Watertown 72, Mass., October 1-2, 1957, 2 pp.

Clock motors whose induced radiations were far above health tolerance have been cannabalized. The spectra of the gammas emitted by the various parts of the movement were recorded with a single-channel gamma spectrometer. In one instance the half-life helped to further identify the isotope concerned. This has indicated various elements that should be avoided in reactor construction and control systems wherever possible (see Section IV for the complete paper).

WAPD-P-657

Sanford E R and Wicoll P A
GOLD FOIL NEUTRON FLUX MONITORS,
Atomic Power Division, Westinghouse Electric Corporation, Pittsburgh 30, Pa., Contract No. AT-(11-1)-Gen-14, (1957), 24 pp. (3 refs).

A series of experiments have been conducted with gold-foil neutron-flux monitors. The absolute thermal flux in the BNL pneumatic tube facility PN-4 was determined to be $2 \times 10^{12}/cm^2$-sec. The BNL and MTR foil-counting methods were compared and found to give $(nvt)_{th}$ values consistent within 5%. One WAPD counting facility was calibrated, relative to BNL and MTR. A second WAPD facility was calibrated utilizing foils irradiated in the ANL standard pile.

WAPD-TM-91

Harris D R
NEUTRON FLUX MAPPING BY LARGE DETECTORS,
Bettis Plant, Westinghouse Electric Corporation, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, October (1957), 9 pp. (2 refs).

Accurate measurement of spatial distribution of neutron flux usually requires the use of small detectors. Such detectors usually are small foils which are irradiated at known positions in an assembly. Radioactivity induced by neutrons in each foil is measured after irradiation by exposing the foil before a counter. The observed count

rate, after corrections for decay of the activity and nuclear content of the foil, is assumed to be proportional to the magnitude of irradiation flux density at the geometric center of the foil. The assumption is usually adequate, considering other experimental errors, if the relative variation of neutron flux density across the foil is small. Because the relative variation of neutron flux across a large detector may not be small, the use of large detectors, such as large foils or gas counters, may introduce an appreciable error in the measured flux distribution. It is shown that the use of large detectors introduces no error in measurement of neutron flux distribution if, and only if, the neutron flux ϕ is distributed as a single eigen function of the equation $\nabla^2\phi = -B^2\phi$. In a central region of a large uniform reactor, the neutron flux is so distributed within a good approximation; hence, large detectors may be employed in accurate measurements of buckling. Perturbations of the neutron flux resulting from the presence of the large detector are ignored.

WAPD-TM-111

Klein Daniel
THE USE OF ISOMERIC STATES FOR NEUTRON THRESHOLD DETECTION,
Westinghouse Electric Corporation, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, February (1948), 10 pp. (3 refs).

Particle reactions such as (n, p), (n, a), (n, 2n), and fission detectors such as U^{238} and Np^{237} foils are the principal sources of fast-neutron detection by activation techniques. This paper describes a fast-neutron detection method which makes use of the existence of isomeric states in certain elements.

WAPD-TN-508

Foderaro A and Obenshain F
FLUXES FROM REGULAR GEOMETRIC SOURCES,
Atomic Power Division, Westinghouse Electric Corporation, P.O. Box 1468, Pittsburgh, Pa., June (1955), 107 pp. (13 refs).

This report consists of a corrected set of equations with the necessary curves for hand computation of fluxes from regular geometric sources. Included in this set are a number of cases which have never before been published.

WASH-292 (Pt.3)-3

Muckenthaler F J
INVESTIGATION OF THE HORNYAK BUTTON AS A FAST-NEUTRON DOSIMETER,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Reactor Shielding Information Meeting, Engineer Research and Development Laboratories, Fort Belvoir, Va., May 12-13, 1955, 2 pp.

The Hurst-type dosimeter which is now being used for fast-neutron dose measurements at the ORNL Shielding Facilities is limited by several features. It cannot be operated in gamma fields above 1 r/hr. The center of detection is not known adequately, and it does not possess sufficient sensitivity for some of the measurements required at the Tower Shielding Facility. Probably the largest problem is keeping the dosimeter in operation.

WASH-292 (Pt. 3)-4

Gamble R L
PROMPT FISSION GAMMA RAYS FROM URANIUM-235*,
Convair, Fort Worth, Texas. Paper presented at Reactor Shielding Information Meeting, Engineer Research and Development Laboratories, Fort Belvoir, Va., May 12-13, 1955, 4 pp.

This paper discusses prompt fission gamma rays from U^{235}. The experimental arrangement is described. The fission took place on the plates of the parallel-plate fission-chamber.

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*This work was done at Oak Ridge National Laboratory under an Oak Ridge Institute of Nuclear Studies Fellowship from the University of Texas.

WASH-408

Wolman Abel, Gorman A E and Lieberman J A
DISPOSAL OF RADIOACTIVE WASTES IN THE US ATOMIC ENERGY PROGRAM,
Division of Reactor Development, Washington, D. C., May 17, 1956, 14 pp.

This report deals with the handling and disposal of radioactive waste products, both high and low level solid, liquid, and gaseous products. The disposal methods discussed include fixation in inert media, special separation of specific isotopes, direct discharge to selected surface or underground geologic formations, and disposal at sea.

ELECTRONIC MATERIALS, COMPONENTS, AND SYSTEMS

ELECTRONIC MATERIALS, COMPONENTS, AND SYSTEMS

A/Conf. 15/P/802

Van Lint V A J and Miller P H, Jr.
ELECTRICAL EFFECTS OF HIGH-INTENSITY IONIZING RADIATION ON NONMETALS,
Presented at Second United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 11 pp.

Experiments have been performed to measure the conductivity induced in nonmetallic substances by ionizing radiation. The effects which are studied in these measurements are due to the excitation of electrons from bound states (valence bands in solids) into conducting states. These phenomena are different from radiation damage as it is usually observed, because the latter is concerned mostly with the more permanent radiation-induced changes associated with the displacement of atoms from their normal positions in crystals or molecules. The effects of electron excitation are expected to manifest themselves primarily in electrical characteristics of the materials, and they are expected to disappear after irradiation in the short time characteristic of electronic de-excitation.

Nonmetallic components discussed are resistors, capacitors, and semiconductors.

AD-143221

Fan H Y and Lark-Horovitz K
IRRADIATION EFFECTS IN SEMICONDUCTORS,
Department of Physics, Purdue University, Lafayette, Ind., June (1957), 32 pp. (119 refs).

Basic information on irradiation damage to semiconductor materials; long on theory, and short on experimental data.

A very complete list of references is included.

AD-150514

Johnson E R
LITERATURE SURVEY ON THE EFFECTS OF RADIATION TO ELECTRON TUBE MATERIALS,
US Army Signal Engineering Labs., Fort Monmouth, N.J. (Stevens Institute of Technology), November 30, 1957, 24 pp. (98 refs).

The effects of nuclear radiation on pure metals used in the manufacture of electron tubes is negligible up to a dose of 10^{20} nvt. In those alloys where precipitation hardening can occur, a possibility of decreased shock resistance exists. No appreciable mechanical or electrical effects due to radiation should occur in alloys for a total dose of 10^{18} nvt. The coefficients of expansion of alloys used in metal-glass seals should change under radiation, causing some incompatibility of the metal-to-glass seal.

The effect of nuclear radiation on emission for cathode surfaces should be negligible up to 10^{20} nvt.

Photomultiplier tubes and tv camera tubes can only be used in extremely low radiation fields. Recommendations for future research are given.

ADC-3091-SR-1

Pfaff E R and Shelton R D
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS, AD91 457
Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, October 10, 1955, 56 pp.

1. A selection of electronic components has been irradiated in the CP-5 research reactor at Argonne National Laboratory. The components were subjected to in-pile operation and testing, and the results of this preliminary testing program have been used to provide guidance and background for the formulation of a more extensive and exacting program, the purpose of which is to determine the effects of nuclear radiation on electronic components. The principal effort has been directed toward planning and exploratory tests which would define the problems of component testing, handling and storing of radioactive components, facility planning, radiation monitoring, and data processing.

2. The components tested included wire, capacitors, resistors, and vacuum tubes. These exploratory irradiations and in-pile operating and testing served more as a test of measuring techniques and operating procedures than as a determination of damage thresholds.

3. In general, the operation of a component was influenced by the flux as well as the time integral of the flux. The wires connecting the components to the measuring instruments were subjected to radiation effects, and there was some difficulty in arriving at a convenient and economical arrangement for compensating for the contribution of the wires to the experimental readings.

4. The capacitance of twisted wire pairs connecting the components to the test equipment was of the order of 10^{-9} farads and appeared to change very little before an integrated thermal flux of 10^{18} nvt was reached. A typical leakage resistance between wire pairs was 3×10^{9} ohms, which dropped by a factor of as much as 40 when the reactor was brought to power. The flux dependent or rate effect varied with the length of irradiation.

5. Ceramic, mica, and paper capacitors with a 10^{-9} farad capacity showed small rate effects and more or less permanent damage, the latter tending to diminish somewhat after irradiation.

6. Carbon and wire-wound resistors of approximately 6000 ohms were affected, respectively, less than 8% and 1% by an irradiation to an integrated thermal flux of 10^{18} nvt.

7. Vacuum tube testing was made difficult by the presence of the radiation field. Large leakages between plate voltage supply lines and high impedance grid circuits resulted in anomalous readings before the trouble was found and corrected. Post-irradiation tests indicated that, although most tubes will operate in some manner to an integrated thermal flux or 10^{18} nvt, they seem more susceptible to damage by handling. Several tubes operated to 10^{18} nvt, but were found to have open filaments when the post-irradiation tests began.

ADC-3091-SR-2 AD-82829

Pfaff E R (Program Director)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Scientific Report No. 2, Phase 1, Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, January 1, 1956, 90 pp.

During this period, several major improvements were made in the method of testing and instrumentation, in addition to the irradiation of selected electronic components.

The instrumentation cabling used on the tests performed during report period No. 1 was replaced with an improved shielded cable and panel board arrangement.

Integrated thermal fluxes were monitored by inserting small cobalt wires with the components being tested. The cobalt wires were then calibrated by comparison with irradiated gold foils. These foils had been previously compared to similar gold foils which had been irradiated in a standard pile at the Argonne National Laboratory. Thermal neutron flux measurements in various reactor facilities were made for the purpose of scheduling component irradiations at a later date.

During this period, a group of polyethylene-insulated wires was compared to a similar group of conductors using polyvinyl-chloride as the insulator. These were compared in a test designed to maximize any leakage effects present. The result of this test showed the polyethylene insulation to be superior as an insulator material while undergoing irradiation in the reactor.

Tests were made on full-sized sample quantities of Types 6AK5 and 1AD4 vacuum tubes, with the result that these tube types were able, in general, to operate throughout the irradiation period of the tests without failure. Prior to insertion these tubes and their control groups had been aged for stabilization.

Following this aging period and during the time of test, all the tubes were subjected, as much as possible, to similar handling.

A group of electrolytic capacitors was tested during this period. They were found to fail after approximately 1.4×10^{17} nvt by becoming virtually short-circuited. A single Type 5U4G rectifier tube was placed in the reactor and connected to an external power supply in such a way that it operated in normal rectifier service, under full load conditions. This tube operated throughout the test run without a significant change in its operation.

A group of four oil-impregnated paper capacitors was tested during this report period without showing signs of failure. They were of the hermetically sealed type, having axial leads, and had capacitances ranging from approximately 0.001 to 0.15 microfarad. A test is now being conducted on groups of 5R4WGB rectifiers and germanium and silicon junction diodes. These components are being tested in full-sized lots, under controlled test conditions, and the results of these analyses will appear in detail in Report No. 3.

ADC-3091-SR-3

Pfaff E R (Program Director)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Scientific Report No. 3, Phase 1, Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, April 1, 1956, 136 pp.

In the period from January 1 to March 31, 1956, a number of electronic components were irradiated by Admiral Corporation in the CP-5 reactor of Argonne National Laboratory. The usual test group of eighteen components was divided into three subgroups; six components constituted a control group, six components were irradiated without operation, and six were operated and tested during the irradiation. All components were given pre-irradiation tests, and extensive post-irradiation tests, including environmental testing, are planned for all components irradiated.

The components were irradiated from 10 to 24 days at a temperature of 50°C. The total exposure varied with the location of the component in the reactor, but typical integrated fluxes were 10^{18} thermal neutrons/cm^2, 10^{18} gammas/cm^2, and 2×10^{15} fast neutrons/cm^2.

The components tested included carbon composition and deposited carbon-film resistors, germanium and silicon crystal rectifiers, high vacuum power and high voltage rectifiers, gaseous-type power rectifiers, miniature and general-purpose triodes, cathode ray oscilloscope tubes, and mica and ceramic capacitors. For the purpose of planning future experiments with camera tubes, material tests of various camera tube parts were performed.

The RC type, carbon composition resistors underwent slight decreases in resistance. At initial reactor power increase, the resistance readings showed a distinct decrease and at an integrated thermal flux of 1.01×10^{18}, there is no evidence of failure in any of the resistors. At the end of the test, the resistance values varied from a plus 1 to a minus 10% change.

RF type, deposited-carbon resistors underwent an early decrease in resistance but recovered and stabilized near the initial value. There were no failures (changes of over 20%) in this group.

The 1N58 germanium rectifiers suffered drastic changes in backward and forward current characteristics before reaching an integrated thermal flux of 10^{18} n/cm^2. The silicon rectifiers showed similar variations, except for two rectifiers supplied by Microwave and one by Bomac. These three units remained operative during the entire test.

All six of the 5R4WGB power rectifiers tested showed over a tenfold apparent increase in emission current before 1.6×10^{17} nvt was reached. The tubes burned out when the normal voltage associated with the standard test circuit was applied.

All the 1Z2 high voltage rectifiers operated throughout the test period without showing serious deviations.

Of the six 0Z4 power gaseous rectifiers tested in the reactor, one operated for the entire test and the remaining five either failed or showed erratic operation.

All six of the 6C4 miniature triodes operated satisfactorily to 7×10^{17} nvt, but three of the six failed before 10^{18} nvt by an interelement short circuit.

The six 3-inch cathode ray oscilloscope tubes operated throughout the test with negligible change in cathode current. Post-irradiation inspection will permit an evaluation of damage to phosphor and glass face plates.

ADC-3091-SR-4

Shelton R D (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, July 1, 1956, 210 pp.

Since July 1955, the Admiral Corporation has been committed under Air Force Contract AF33(616)-3091 to study the effects of nuclear radiation on electronic components. This report is concerned with components irradiated in the CP-5 reactor of Argonne National Laboratory during the period from April 1 to July 1, 1956. A variety of electron tubes, capacitors, and resistors were tested before, during, and after exposure to irradiation of the order of 10^{18} thermal neutrons/cm^2, 10^{18} gammas/cm^2 and 10^{15} epi-cadmium neutrons/cm^2. The eighteen components comprising a test were divided into three groups of six each; a control group, a passive group which was irradiated to 10^{18} integrated thermal flux, and an active group which was operated and tested during the irradiation to 10^{18} integrated thermal flux.

Vidicon and image orthicon camera tubes exhibited severe fractures in the glass envelopes after irradiation in the reactor.

Voltage regulator tubes 5651, 0A2, and 0B2 suffered increases of firing potential under continued irradiation, but were not influenced perceptibly by changes in the rate of irradiation.

Two groups of twin diodes, 5896 and 6AL5, operating as rectifiers in the reactor, underwent a slight decrease in output of voltages and emission currents.

The glass envelopes of 829-B beam power amplifiers developed multiple fractures during an irradiation to 1.2×10^{17} integrated thermal flux.

All of the six 6080 twin diodes survived an irradiation to 10^{18} integrated thermal flux.

Six transmitting-type power tetrodes, 4-65A, behaved erratically during irradiation and failed before 10^{17} integrated thermal flux was attained.

Mica and ceramic capacitors showed little change of capacitance and no failures.

Paper capacitors showed a decided decrease in capacitance during irradiation.

The RB-type precision wire-wound resistors remained stable during irradiation.

ADC-3091-SR-5

Shelton R D (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, October 15, 1956, 235 pp.

A variety of capacitors, resistors, and electron tubes were irradiated in the CP-5 reactor during the period of time from July 1 to September 30, 1956. In general, the components were irradiated over a period of several days to integrated fluxes of approximately 10^{18} thermal neutrons/cm^2, 10^{15} fast neutrons/cm^2, and 10^{18} gammas/cm^2.

The temperature of the components during irradiation was 50°C and above, depending on the position of the component in the reactor, the power dissipated by the component, and the amount of air cooling necessary to keep the temperature within the recommended range.

Mica capacitors tested during this period appeared to change rapidly during the early part of the irradiation and to stabilize as the irradiation progressed. The changes were generally less than 5%. In some instances, the capacitance decreased while in others it increased. Except for small rate effects, the dissipation factor underwent only small changes.

Capacitors with paper dielectrics displayed a marked susceptibility to damage, especially in the increase in dissipation factor. No general statement can be made concerning the damage pattern of paper capacitors, except that those from the same manufacturer behaved similarly. It appeared that the greater irregularities were associated with oil-impregnated paper capacitors.

Plastic capacitors suffered an increase in dissipation factor and a final breakdown of dielectric.

The resistance between the pins of an amphenol plug decreased by more than a factor of 30 when the reactor was raised to full power and increased by the same magnitude when the reactor was shut down. In addition to these rate effects, there was an over-all, long-term decrease in resistance.

All of the resistors tested during this period were of the fixed, wire-wound type. The resistance was measured before, during, and after irradiation.

A comparison of pre- and post-irradiation data for fixed, wire-wound, precision resistors revealed that the average resistance change resulting from irradiation was less than 0.3%.

Wire-wound, power resistors showed little or no damage, except for temporary fluctuations during the in-pile tests.

Damaged vacuum tubes showed evidence of gaseousness, glass discoloration, and sometimes glass fracture. The 1AD4 subminiature pentode survived the irradiation with little damage. Five of six 2C40 lighthouse triodes operated throughout the test, but fractured before a post-irradiation test could be prepared. Cathode ray tubes suffered from glass discoloration and decreased cathode current, but remained operative.

The trend followed by three 4D21 power tetrodes under irradiation is difficult to describe simply. All tubes showed decreased emissions, but displayed different variations in the control grid voltage required to maintain a constant plate current.

The 583 clipper diodes exhibited a large increase of emission followed by a greatly reduced emission. Post-irradiation examination showed a fractured envelope.

The voltage drop across the 5643 thyratrons appeared to increase because of irradiation.

The 5819 photomultiplier survived the irradiation, but the dark current appeared to be a sensitive function of the reactor power.

Image orthicon tubes failed rapidly, exhibiting symptoms of gas. All of the envelopes were found to be fractured severely in the post-irradiation examination.

The 5902 subminiature pentodes withstood the irradiation, showing only a slight decrease in transconductance. The plate and screen currents remained essentially constant, but the control grid current increased steadily to a value above that permitted by MIL-E-1/175B.

ADC-3091-SR-6 AD-121223
Shelton R D (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS, Electrical Engineering Division, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, January 1, 1957, 300 pp.

A variety of electronic components has been tested before, during, and after exposure to nuclear radiation. The irradiation facilities included the CP-5 reactor, where most of the irradiations were performed, the MTR of the National Reactor Testing Station, and a Co^{60} facility. The components, some of which were under normal operating conditions, were irradiated over a period of several days. The radiation environment varied considerably, but typical values for the CP-5 were 2×10^6 R/hr for gammas, 5×10^9 epicadmium neutrons/cm^2-sec and 10^{12} thermal neutrons/cm^2-sec.

The several electron tubes tested included the following types: 2D21, 371B, 3B28, 0Z4, and 6AG7-Y. Only two of six 2D21 Xenon-gas thyratrons operated satisfactorily to the end of the standard irradiation. Three of the four 371B high vacuum, half-wave, high voltage rectifiers failed in less than four hours of irradiation. The fourth 371B operated throughout the test, but suffered a drastic reduction in plate current.

The 0X4 cold-cathode, full-wave rectifier operated with little change for the entire irradiation period. The 6AG7-Y pentode amplifier showed no evidence of damage. Several 1N21B silicon diodes were irradiated both in the CP-5 reactor and in a Co^{60} source. The backward resistance deteriorated rapidly in the early part of the irradiation, but three of six diodes completed the test without failure.

Every ceramic capacitor tested during this period remained within tolerance for the entire irradiation.

Fixed mica capacitors CM35B622J from Micamold and Cornell Dubilier remained within tolerance, whereas those from Aerovox did not. Changes in mica button capacitors averaged less than 1%.

Plastic capacitors varied in their radiation resistance. The OG6-103 failed by shorting during irradiation, but the LS4-103 remained within tolerance.

Variable resistance potentiometers of composition type supplied by Allen Bradley appeared to suffer considerably less damage than those from Chicago Telephone.

Composition-type resistors decreased in resistance from 3 to 20% during the CP-5 irradiations.

Wire-wound resistors were virtually unaffected by irradiation except for a slight general increase in resistance.

All wire-wound, power rheostats remained within tolerance for the entire irradiation period.

Printed circuits were also tested.

ADC-3091-SR-7

Shelton R D (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS, Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, April 1, 1957, 500 pp.

A variety of electronic components has been tested before, during, and after exposure to nuclear radiation. The irradiation facilities included the CP-5 reactor, where most of the irradiations were performed, the MTR of the National Reactor Testing Station, and a Co^{60} facility. The components, some of which were under normal operating conditions, were irradiated for several days. The radiation environment varied considerably, but typical values for the CP-5 were 2×10^6 R/hr for gammas, 5×10^9 epicadmium neutrons/cm^2-sec and 10^{12} thermal neutrons/cm^2-sec.

Electron tubes tested consisted of the following: 2C40, 2K50, 3JP12, 371-B, 5703, 5719, and 6198.

The 2C40 UHF triode showed some change in plate current during in-pile. Five of the six active tubes survived post-irradiation.

The 2K50 thermally tuned klystrons failed in-pile; post-irradiation tests indicated glass-to-metal seal fractures.

Both 3JP12 cathode ray tubes survived irradiation; some envelope discoloring occurred.

All of the 371-B high vacuum half-wave rectifiers failed in-pile.

The 5719 and 5703 subminiature triodes increased in plate current and transconductance and, in some instances, grid current.

Both 6198 vidicon camera tubes failed in-pile, each displaying envelope fractures in post-testing.

The 1N58 germanium crystal diodes failed during irradiation.

Every fixed mica capacitor, with the exception of the CM35C622J, remained within tolerance in-pile; these decreased 12% from their initial value.

In several instances the RN style, 1 and 2%, deposited film resistors exceeded their specified resistance tolerance in-pile.

The RW wire-wound, power-type resistors, in general, remained stable during irradiation; the resistance stability appeared largely dependent on manufacturer.

Potentiometers - RV4NATSG501B also varied with manufacturer, showing as much as 30% change in-pile. Printed circuit boards of five basic materials were tested: glass epoxy, glass melamine, nylon phenolic, paper phenolic, and teflon. No evidence of

permanent damage was indicated. In-pile change in leakage resistance of the boards are believed to be caused by temperature and a radiation-induced current carrier phenomenon.

ADC-3091-SR-8

Schlueter A W (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, July 1, 1957, 674 pp.

A variety of electronic components has been tested before, during, and after exposure to nuclear radiation. The irradiation facilities included the CP-5 reactor, where most of the irradiations were performed, the MTR, and a Co^{60} facility. The components, some of which were under normal operating conditions, were irradiated for several days. The radiation environment varied considerably, but typical values for the CP-5 were 2×10^6 R/hr for gammas, 5×10^9 epicadmium neutrons/cm^2-sec and 10^{12} thermal neutrons/cm^2-sec.

Both active and passive groups of temperature compensating, general-type ceramic, glass, and fixed mica capacitors survived the irradiation. All remained within tolerance with no apparent difference between the two groups.

Active and passive experiments of the fixed mica capacitors showed little damage with a similarity between the groups. The CM35B622J capacitor, manufactured by Aerovox, decreased out of tolerance.

Six air trimmers were tested without apparent damage.

The unfinished capacitors, elements of the CY30 capacitors, and the unfinished resistors essentially all exceeded their MIL tolerances.

The F-6867 traveling wave amplifier tube, the 4C35 hydrogen thyratron, and the 5R4 therminonic rectifier tube failed in-pile because of glass-to-metal seal failure.

The 6L6WGB beam power, the 5639 subminiature video amplifier, the 5840 subminiature pentode, the 5670 miniature twin triode, and the 5876 subminiature UHF survived the irradiation, but had control grid currents in excess of the maximum specification.

The 5517 cold cathode, half-wave, gas rectifier, the 6112 subminiature twin triode, and the 5751 miniature hi-mu twin triode all survived the CP-5 experiment.

Though the plate current increased, the 5687 twin triode survived the test.

Grid and plate current of the 5744 subminiature triode exceeded the maximum tolerance.

The 5819 photomultiplier and the 6198 vidicon camera tubes survived irradiation with reduced output currents.

The following components survived the MTR irradiation without exceeding their tolerance: fixed button micas, CB11PX681G, CB21PX101G; ceramic types, CC25CH430J; and fixed mica, CM35B622J capacitors; wire-wound RW31G20R0 resistors; and voltage regulator OA2 and OB2 tubes.

The fixed composition resistors, RC20BF101J, RC32GF101J, and RC32GF102J, all decreased 50% from their initial values.

The 6AL5 twin diode and the 5518 subminiature triode tubes failed in the MTR.

One 1Z2 high voltage rectifier failed and two others showed some damage in the MTR.

ADC-3091-SR-9

Schlueter A W (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, October 1, 1957, 728 pp.

Electronic components were tested before, during, and after exposure to nuclear radiation. The irradiation facilities included the CP-5 reactor, the MTR, and a Co^{60} facility. The components, some of which were under normal operating conditions, were irridiated for several days. The radiation environment varied considerably, but typical values for the CP-5 were 2×10^6 R/hr for gammas, 10^{12} thermal neutrons/cm^2-sec, and about 10^8 neutrons/cm^2-sec beyond 2.5 Mev.

Steatite and glass epoxy printed circuit boards underwent apparent in-pile changes due to ion conduction in the surrounding air; these changes were reduced by acrylic spray. Boards were warped and blistered in the post-test.

All quartz crystal units decreased in resonant frequency; approximately half ceased to oscillate.

Paper capacitors failed partially or entirely due to gas evolution.

Plastic dielectric capacitors increased 10% in capacitance.

Damage to fixed (composition film VHF) resistors varied by manufacturer; some exceeded tolerance.

The following components were essentially not affected by the CP-5 irradiation: wire-wound, power-type rheostats; fixed, wire-wound resistors; tube types: CD-18, 5Y3, 5993, 5899 (Sylvania and General Electric survived, Sonotone failed), 6021 (Sylvania and General Electric survived, Raytheon became gassy); printed circuit assemblies; and fixed composition resistors (decreased due to humidity effects).

Damage to deposited film and fixed-film power resistors may be related to the boron content.

The following tubes suffered from glass failure: 2C39, 4C35, 4J52, 5C22, and 6384.

The following components drew grid current: 12AT7 (all active tubes failed MIL specification, all had excessive grid current); 5636 and 5814 (amount varied with manufacturer); 5725/6AS6 (little change); 6189/12AU7; 6111 (plate current decreased); and 6005/6AQ5 (failed MIL specification).

The following components were not affected by the Co^{60} radiation: temperature-compensated and general-type ceramic capacitors, glass capacitors, fixed and button-type mica capacitors, 3B28, 271B, 4-65A, and 4D21.

Co^{60} irradiation affected: IN58 (semiconductor diode during irradiation) and paper dielectric capacitors.

In the Materials Testing Reactor (MTR), temperature-compensated ceramic capacitors went out of tolerance, but returned to normal during the reactor down period; plastic dielectric capacitors were extremely erratic; and fixed mica capacitors went out of tolerance and were erratic.

The following components were not affected by the MTR fields: wire-wound resistors, accurate wire-wound, OZ4, 6AU6 and 6BE6.

Composition resistors in the MTR exhibited changes which result normally in the processes of aging, heating, and dehumidification.

Most irradiated components were not affected by vibration or humidity.

Numerous tables of dates and test circuits are included.

Ceramic and thyratron tubes were also tested.

ADC-3091-SR-10

Schlueter A W (Editor)
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Electrical Engineering Department, Admiral Corporation, Chicago 47, Ill., Contract No. AF33(616)-3091, January (1958), 256 pp.

Electronic components were tested before, during, and after exposure to nuclear radiation. The irradiation facilities included the CP-5 reactor and a Co^{60} facility. The radiation environment varied considerably, but typical values for the CP-5 were 2×10^6 R/hr for gammas, 10^{12} thermal neutron/cm^2-sec, 5×10^9 epicadmium neutrons/cm^2-sec, and about 10^8 neutrons/cm^2-sec beyond 2.5 Mev.

The following components were essentially unaffected by nuclear radiation: AFRT14E, AFRT14J, AFRT14K, AFRT19E, and AFRT19J; RA15A1SD502AJ, RA30A1SD153AJ; RP101SJ-; RV4LAYSA-; and LC-2 pentode.

The CP04A1EE104M capacitors were damaged due to gas evolution.

The TG75-202 capacitors capacitance increases of 14%.

RD31P- and RD65P-resistors all increased in resistance; the greatest increase occurred in those components having the largest resistance values.

RN70- and RN75-resistor damage was related to boron content.

AT cut crystals exhibited a decrease in resonance frequencies with the exception of the CR-24/U type. All other cuts exhibited an increase in resonance frequencies. One-half of the samples ceased to oscillate.

The typical radiation environment of the Co^{60} source is 2×10^5 R/hr in 1.25 Mev gammas.

In the Co^{60} source, the CP- capacitors were damaged due to gas evolution.

A large number of tubes, resistors, and capacitors were unaffected by Co^{60} gamma irradiation.

Additional tests include humidity, vibration, altitude, and heat.

ADC-5464-SR-1

Pfaff E R (Program Director)
THE EFFECT OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS,
Phase 2, Electrical Engineering Departments, Admiral Corporation, Chicago 47, Ill.,
Contract No. AF33(616)-5464, April (1958), 76 pp.

Electronic components were tested before and during exposure to nuclear radiation. The irradiation facility was the CP-5 reactor. The radiation environment varied considerably with the location in the reactor. Typical values for the isotope facility of the CP-5, were 2×10^6 R/hr for gammas, 10^{12} thermal neutrons/cm^2-sec, 5×10^9 epicadmium neutrons/cm^2-sec, and about 10^8 neutrons/cm^2-sec above 2.5 Mev.

The Phase 2 test program for transformers, dynamotors, and wires is presented in this report.

A variety of insulated wires was irradiated during the first quarter of the Phase 2 testing program. The insulations and wires studied were: hook-up wire, polyvinyl insulation with various combinations of shields and braids; magnet wire with various insulation coatings; and two types of high temperature insulated wires.

AE-0057-1

RADIATION DAMAGES IN METALS AND SEMICONDUCTORS AND AFTER GAMMA-IRRADIATION,
Atomnaya Energiya, Vol. 3, p. 562 (1957).

The effects of gamma radiation on germanium and copper were investigated. The germanium was irradiated in the temperature range from liquid nitrogen temperature to room temperature. The irradiation of n-Ge causes a decrease of the "carrier number." After a long irradiation n-Ge is converted into p-Ge. An investigation of the temperature dependence of the Hall effect showed that two acceptor levels are formed in the n-Ge. The defects appearing under gamma radiation are evenly distributed within the mass of the sample, which makes it possible to estimate the influence of the defects on different physical properties.

AECD-3810

Faris Frank E
RADIATION EFFECTS QUARTERLY PROGRESS REPORT FOR APRIL-JUNE 1954,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8,
November 1, 1954, 59 pp. (7 refs).

This report discusses graphite, metals, insulators, and irradiations. Cyclotron operation and development are discussed, and irradiations were made to determine the effect of

radiation on the following properties: thermoelectric power of graphite; stored energy of graphite; thermal conductivity of graphite; and irradiation effects in thorium.

The anomalous low temperature thermal conductivity of graphite samples measured previously has been explained by two different theories. The theory held by the group at this laboratory is that a small amount of intergranulor carbon contributes at T^3 dependence to the conductivity. The intrinsic conductivity is held to be T^2 dependent in the temperature region where boundary scattering predominates. Klemens holds that the anomalous conductivity is intrinsic to graphite and depends only on the ratio of the crystallite thickness to the crystallite width.

The conclusion reached is that the thermal conductivity of graphite at low temperatures has a T^2 dependence, and that the higher exponent previously found is to be explained by a two-medium theory. This theory is explained.

The calculation of the contribution of the conduction electrons in graphite to the thermal resistivity has been completed, and a report is being issued.

An apparatus for the measurement of the magnetic susceptibility of solids at liquid nitrogen temperatures has been constructed.

Mechanism of pore formation associated with the Kirkendall effect in a typical report will show that two-dimensional tensile stress is established in Kirkendall-type diffusion specimens on the side of the interface suffering a net loss of atoms. In the presence of this stress, voids larger than a critical size will grow by absorbing vacant lattice sites when the concentration of such sites is maintained at its equilibrium value. A mechanism is proposed by which the tensile stress can nucleate voids of this critical size or larger. Thus, the proposed mechanism of nucleation and growth of the voids formed in connection with Kirkendall-type diffusion experiments can operate without the existence of an excess concentration of vacancies.

As a result of annealing studies of cyclotron-irradiated thorium, it is believed that this annealing state may be associated with the motion of interstitial atoms in thorium.

Tensile properties of iodide thorium at room temperatures are also discussed along with displacement energy in metals.

AECD-4218

Sherrard George R
TRANSCRIPT SUMMARY OF VARIOUS IRRADIATION DAMAGE REPORTS ON ELECTRICAL AND THERMAL INSULATING MATERIAL,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, 10 pp. (17 refs).

This document contains tabulated information on insulating materials, plastics, hook-up wire, ceramic materials, elastometers, and cables..

AECU-2267

Klontz Everett Earl
PRODUCTION OF LATTICE DEFECTS IN GERMANIUM BY ELECTRON BOMBARDMENT,
Department of Physics, Purdue University, Lafayette, Ind., June (1952),75 pp. (38 refs).

The degree of damage produced by bombardment is a function of the energy, flux, and temperature of bombardment. Conductivity-flux curves for several bombardment energies and temperatures have been obtained.

Heat treating the samples heals out bombardment-produced defects. The extent of healing has been followed by taking Hall and resistivity values as a function of temperature, and depends on the temperature to which the sample is heated. Restoration of the original resistivity can be attained by heat treatment at 450°C for 24 hours, again in agreement with the results after quenching and nucleon bombardment.

This report also reviews semiconductor theory and equations, and gives a historical survey of lattice defects in germanium.

AECU-3808

Vook Frederick L
LENGTH AND RESISTIVITY CHANGES OF GERMANIUM UPON LOW TEMPERATURE DEUTERON IRRADIATION AND ANNEALING,
Thesis for University of Illinois, Urbana, Ill., May (1958), 59 pp. (32 refs).

Simultaneous measurements of length and resistivity of high purity germanium single crystals were made upon irradiation and annealing. The specimens were initially irradiated at 25°K with deuterons of average energy 10.2 Mev to an integrated flux of 6.2×10^{16} deuterons/cm^2 and annealed to room temperature. The specimens were then irradiated at 85°K to an additional flux of 9.2×10^{16} deuterons/cm^2 and annealed to 364°K. The specific length expansion for both bombardments was found to be $\Delta L/L = 1.5 \pm 0.2 \times 10^{-21}$ deuterons/cm^2. The annealing for both runs showed a gradual recovery of the expansion beginning at approximately 200°K with recoveries of approximately 50% by 300°K and 85% by 360°K. The resistivity measurements agreed generally with previous results. An irreversible resistivity increase occurred on annealing between 85° and 140°K. The resistivity decreased irreversibly by a factor of 10^3 between 150° and 200°K.

The irreversible annealing curves of the resistivity and volume expansion therefore do not show parallel behaviour. If the damage is interpreted in terms of point defects, and if the length change recovery is caused by interstitial-vacancy annihilation, then the resistivity changes on annealing below 200°K are possibly caused by the association of defects in various cluster models. A possible cluster model that can explain the present length and resistivity changes on bombardment and annealing, as well as recent small angle X-ray scattering data, consists of clusters of interstitials and vacancies not centered at the same point. It is possible that the vacancy and interstitial clusters may be produced directly upon irradiation in a rather coarse distribution suggested by previous small angle X-ray scattering data at ~90°K. If so, present displacement theories are in serious error.

AERE-M/R-649

Madsen P E
THE CALIBRATION OF THERMOCOUPLES UNDER IRRADIATION IN B.E.P.O.,
Atomic Energy Research Establishment, Harwell, Berkshire, England, January (1951), 21 pp.

The thermoelectric emf of a chromel-alumel thermocouple at the freezing points of tin

and lead and of iron-constantan, copper-constantan and platinum-platinum/13% rhodium thermocouples at the freezing point of lead have been measured in B.E.P.O.

Of the four couples investigated at the freezing point of lead, the platinum-platinum/13% rhodium couple gave the most reproducible behavior, and no significant change in the couple reading was introduced by irradiation. The other couples all showed significant increases, chromel-alumel giving the biggest effect--1.1°C.

At the freezing point of tin, chromel-alumel showed no significant change at first, but on prolonged irradiation gave a statistically significant decrease of 0.47°C. In all the couples, the mean of the readings when the pile was working was significantly different from when it was shut down, but this effect was small except for the chromel-alumel couple at 327°C when it was about 0.5°C.

AIEE-55-694

Pigg J C, et al.
THE EFFECT OF REACTOR IRRADIATION ON ELECTRICAL INSULATION,
Presented at the AIEE Fall General Meeting, Chicago, Ill., October 3-7,1955, 14 pp. (9 refs).

Insulation in its broadest sense implies a method of isolating a system. In electrical systems, insulation may also serve as part of a component as in the case of a dielectric; however, for the present purpose, insulation will be considered to be a means of isolating an electrical system.

Adequate insulation may be defined as that degree of isolation which holds spurious circuits below the maximum value permitted by engineering tolerances. The requirements for adequate insulation vary radically as the nature of the circuit and its environment are changed. For example, a shorted stub may be an open circuit at one frequency, an inductance or capacitance at another frequency, or a short circuit at some other frequency and DC. Conversely, a polystyrene rod which is an insulator for DC may be used as an antenna element at microwave frequency. The voltage, frequency, application, and environment of the circuit determine the nature of the insulation requirements.

The presence of a radiation field produces a new and drastic element in the environmental factor which alters the performance of insulation both in quality and nature. Of these two, perhaps change in quality should be considered first since it is a natural extrapolation of normal experience with such materials.

This paper includes a brief review of the usual causes of insulation deterioration. The effect of radiation on these processes is discussed. It is observed that additional factors are present when an insulation is in a radiation field which change both the quality and nature of insulation.

AIEE-55-741

Klein P H and Mannal Clifford
THE EFFECTS OF HIGH-ENERGY GAMMA RADIATION ON DIELECTRIC SOLIDS,
Presented at the AIEE Fall General Meeting, Chicago, Ill., October 3-7, 1955, 15 pp.

The kinds and magnitudes of radiations present in the various locations near nuclear reactors are discussed, as well as the mechanisms of interaction of radiation with matter, namely, group fragmentation, molecular scission and polymerization.

Techniques and locations for obtaining high dose rates are presented. Results of 60-cycle short-time voltage breakdown tests on polyethylene, cellulose acetate, and polyvinyl chloride films along with Formex-varnished wire are given as a function of integrated dose up to 10^8 roentgens. Extensive electrical tests on a mica-glass-silicone-resin insulation simulating that used in the electromagnetic pump for the Submarine Intermediate Reactor are described. Measurement of mechanical property changes of irradiated resins by means of a newly developed penetrometer is presented.

AIEE-CP-55-103

Callinan T D
THE EFFECT OF GAMMA RADIATION ON LIQUID DIELECTRICS,
Presented at the AIEE Winter General Meeting, New York, NY, January 31 to February 4, 1955, 11 pp.

The commercial liquid dielectrics of today have been developed, over a period of 40 years, to cool windings, store energy, and sustain high voltages at elevated temperatures in the presence of active metals. The efficiency of these liquids depends upon their inherent stability under operating conditions. Thus, any substance which would increase in viscosity with time would endanger the heat-transfer characteristics of the equipment and lead to excessive temperatures and thermal failure. Again, rearrangement of the molecular structure would be expected to result in changes in the dielectric constant and loss factor of the substance and, consequently, of its energy storage characteristics. Finally, the excessive formation of gases or other regions of nonuniformity in the liquid would lead presumably to early breakdown and electrical failure of the equipment at high voltages.

The successful industrial development of nuclear power necessitates using liquid-filled components in the vicinity of sources of intense gamma radiation. Due to photoelectric effects, Compton scattering and ion-pair formation, in substances in such fields, ionized and excited molecules, free and atomic radicals are generated in commercial liquid dielectrics resulting in marked changes in the physical properties of the liquids.

From test results it is apparent that gamma radiation can transform dielectric liquids appreciably, either by converting them into solids or by decomposing them into acids and gases. By using the factor G_A as a characteristic, it is possible to evaluate various liquids and to calculate the changes in liquids to be expected in equipment subjected to irradiation. Finally, it would appear that additives are available which can increase the stability of such liquids subjected to gamma fields.

ANL-5667

Turner Louis A (Division Director)
PHYSICS DIVISION SUMMARY REPORT SEPTEMBER - DECEMBER 1956,
Argonne National Laboratory, Lemont, Ill., Contract No. W-31-109-Eng-38, February (1957)

This report includes a section dealing with radiation damage to dielectrics. Plexiglas M2 was given successive doses of 1.32 and 0.55 x 10^7 r for an accumulated dose of 1.87 x 10^7 r. After standing for 2 days following the second irradiation, the current through the specimen was observed throughout four successive 1-week intervals.

ANL-HLH-1

Creagen R J
EXPOSURE OF VACUUM TUBES IN PILE,
Argonne National Laboratory, P.O. Box 5207, Chicago 80, Ill., February 5, 1947, 3 pp.

Vacuum tubes were exposed in the No. 8 compartment of the "goat hole" of CP-3 for various lengths of time with no definite change in characteristics of the tubes involved. There seemed to be a slight increase in plate current (grid and plate voltage being held constant) with exposure, but because of the qualitative nature of the experiment, nothing specific can be said on this point.

APEX-347

Crittenden, J
RADIATION EFFECTS ON THE G-E CERAMIC VACUUM TRIODE,
General Electric Co., Atomic Products Division, Aircraft Nuclear Propulsion Department, Cincinnati 15, Ohio, Contract Nos. AF33(038)-21102 and AT-(11-1)-171, January (1958), 10 pp.

Because nuclear radiation may cause changes in the characteristics of an electronic component, the General Electric Aircraft Nuclear Propulsion Department has conducted a number of experiments to determine the nature and the extent of radiation effects on electronic equipment. In or near a reactor, three primary radiations--the thermal neutron, the fast neutron, and the gamma ray--cause the most severe effects.

When the ceramic vacuum tube was conceived, its high temperature and radiation-tolerance potentials were quickly recognized. As a number of these ceramic tubes became available, they were subjected to high-temperature tests, radiation tests, and simultaneous high-temperature and radiation tests. The early results showed little change in the tubes and practically no change that could be attributed to radiation. Later tests verified this finding.

This report discusses composition and functional characteristics of the ceramic vacuum triode.

APEX-357 X-21934

Collins C G, et al.
ESTIMATED RADIATION STABILITY OF AIRCRAFT COMPONENTS,
General Electric Co., Atomic Products Division, Aircraft Nuclear Propulsion Department, Contract Nos. AF33(038)-21102 and AT-(11-1)-171, September (1958), 139 pp.

This report presents extensive data on estimated and observed radiation damage to the materials and components most likely to limit the performance life time of aircraft powered by a nuclear power plant. The general classes listed are hydraulic-pneumatic components, electrical components, and electronic components.

APEX-365

Lachman J C
CALIBRATION OF RHENIUM-MOLYBDENUM AND RHENIUM-TUNGSTEN THERMOCOUPLES TO 4000°F,

General Electric Co., Atomic Products Division, Aircraft Nuclear Propulsion Department, Cincinnati, Ohio, Contract Nos. AF33(038)-21102 and AT-(11-1)-171, April 30, 1958, 16 pp.

Calibration curves to 4000°F have been established for rhenium-molybdenum and rhenium-tungsten thermocouples in vacuum, hydrogen, or inert atmospheres. The practical application to rhenium-molybdenum thermocouples is limited to measurements up to 3200°F. Rhenium-tungsten thermocouples, however, measure temperatures up to and apparently higher than 4000°F.

APEX-462

Friedman A, et al.
THE EFFECT OF REACTOR RADIATION AND TEMPERATURE ON SILICON JUNCTION DIODES,
General Electric Co., Atomic Products Division, Aircraft Nuclear Propulsion Department, Cincinnati 15, Ohio, Contract Nos. AF33(600)-38062 and AT-(11-1)-171, February (1959), 167 pp. (6 refs).

The goal of this project is to obtain information on the effect of temperature (up to 300°C) and nuclear reactor radiation on the performance of specific types of silicon junction diodes, and to utilize this information, insofar as possible, to make recommendations which may lead to improved diode function under these experimental conditions.

Of particular interest has been the effect of high temperature and reactor radiations on diode forward and reverse characteristics, switching characteristics (speed of response), noise, Zener voltage, and Zener slope characteristics.

The experiments reported herein were performed at the Brookhaven National Laboratory Reactor. After initial investigation of the various available irradiation facilities in the reactor, a 1-inch facility (hole W-13) and two 4-inch facilities (holes W-12 and W-14) were chosen. The positions for irradiation were all 10 feet in from the pile face, and the ambient temperature was about 25°C.

The flux levels and spectra chosen were such that the rates of radiation effects were sufficiently slow for observation and yet fast enough for considerable diode damage to result within a reasonable irradiation period.

Sample flux values and the cadmium ratio, as measured at the position for irradiation in W-12, are given below for a reactor power of 15 Mw. The flux values in the other two holes were comparable.

Thermal neutron flux: 5.1×10^{11} n/cm^2-sec

Resonance (epicadmium) neutron flux (0.57 ev $\leq E_n \leq$ 1 Mev): 2.6×10^{10} n/cm^2-sec

Fast neutron flux (1 Mev $\leq E_n \leq$ 2 Mev): 2.2×10^{8} n/cm^2-sec

Fast neutron flux ($E_n \geq$ 2 Mev): 3.3×10^{8} n/cm^2-sec

Gamma-ray intensity: 2.7×10^{4} r/hr

Cadmium ratio: 20

In order to determine the radiation environment, a series of neutron flux and gamma-ray measurements accompanied the study of radiation effects. The values of neutron flux were obtained by activation of gold, cobalt, and sulfur foils. Gamma-ray intensity was

determined by measuring the induced oxidation of ferrous to ferric ions. A detailed discussion of these measurements and the neutron spectra and gamma-ray values employed are given under Neutron and Gamma-Ray Flux Measurements.

In the course of this study, 11 types of commercial silicon junction diodes were irradiated. The table on page 6 summarizes the total number of each type irradiated and the associated experimental conditions. Life tests lasting 1000 hours were performed for five types of diodes and these are listed on page 7 which also gives the experimental conditions.

The diodes to be irradiated were mounted on a suitable material and were enclosed in aluminum containers. For 150° and 300°C experiments, the diode assemblies were placed in furnaces equipped with temperature controls. The measurement of forward and reverse characteristics was accomplished by curve-tracing circuits which displayed the characteristic curves on an oscilloscope. The reverse characteristic curves extended to the Zener voltage and Zener slope region. The characteristic curves of the diodes under irradiation were displayed and recorded on film, successively, by an automatic switching and recording system. This instrument, which can accomodate up to 100 diodes and which was built by ANSCO personnel for this study, was found to be essential for in-pile experiments because of the relatively large number of diodes irradiated during each experiment and the continuous nature of the radiation effects. A photograph of the automatic switching device and details of the circuits employed appear in the section entitled Experimental Procedures.

The response to irradiation was found to vary greatly among diodes even of the same type. A few general observations, however, can be made. Our results showed that radiation invariably increased the forward resistance of a diode. This effect was more pronounced at 25°C than at elevated temperatures. The behavior in the reverse direction did not follow any regular pattern. In general, however, it can be said that at room temperature reverse current usually increased as a result of radiation, but the magnitude tended to fluctuate somewhat in the course of the experiments. The normally higher reverse currents at 150°C increased considerably upon exposure in the reactor. If at the end of irradiation of 150°C, the temperature was lowered to 25°C, it was found that the forward resistance markedly increased and reverse current decreased considerably. Switching time of diodes invariably decreased with irradiation. Post-irradiation measurement of diode noise indicated that the noise level varied greatly among diodes, from microvolts to millivolts, irrespective of type.

The experimental results of forward and reverse characteristics are presented as a family of characteristic curves with nvt as a parameter. A typical sample is shown on page 8. The effect of radiation on switching characteristics is shown on page 9. Pages 10 through 19 summarize, by diode types, the limits of the peak forward voltage drop of all irradiated diodes as a function of epicadmium nvt at different temperatures. Detailed experimental data are to be found under Experimental Results.

At the end of this report there is a discussion which considers the effect of radiation on diode behavior and which suggests approaches that may lead to improved diode function. The discussion points out that short initial minority carrier lifetime is desirable. A comparison is also made of the damage to silicon induced in the radiation environment utilized and the damage to be expected 10 feet from a "swimming pool" reactor surrounded by a foot of water and an inch of boron carbide. It is estimated that an nvt in the latter situation would cause about 4.4 times as much bulk damage in silicon as would an equal epicadmium nvt from the spectra employed in this study.

APEX-477

Mott J E
RADIATION AND TEMPERATURE TESTS OF MINIATURE TRANSISTOR AMPLIFIERS,
General Electric Co., Atomic Products Division, Aircraft Nuclear Propulsion Department, Cincinnati 15, Ohio, Contract Nos. AF33(600)-38062 and AT-(11-1)-171, May (1959), 32 pp.

This report presents the results of radiation and temperature tests run on two different types of miniature transistor amplifiers. Performance curves are shown, and an analysis of the results leading to a possible method of failure prediction is given.

One of the amplifier types was successfully tested to a temperature of 150°C, gamma irradiation of 4.7×10^7 roentgens, and a fast-neutron dosage of 7.0×10^{13} nvt (epicadmium). These results place the use of such an amplifier within the realm of feasibility as an airframe-mounted control component.

BOE-D5-1183

Keister G L and Stewart H V
PRELIMINARY REPORT OF AN INVESTIGATION OF THE EFFECTS OF NUCLEAR RADIATION ON SELECTED TRANSISTORS AND DIODES,
Boeing Airplane Company, Seattle 14, Wash., Contract No. AF33(038)-19589, August 22, 1956, 157 pp.

The effects of nuclear radiation upon selected transistors and semiconductor diodes have been observed during irradiation in the Materials Testing Reactor (MTR) and the MTR Gamma Facility. The following effects were noted:

1. A gamma flux of 2×10^6 r/hr induced a measurable voltage across a p-n junction.

2. Transient changes were noted in the collector characteristic due to gamma irradiation. This damage was characterized by a large increase in the leakage current which healed from seconds to minutes after removal of the flux. Sensitivity of various transistors to this effect varied by several orders of magnitude. This effect was observed for a gamma flux of 5×10^4 r/hr and of 2×10^6 r/hr.

3. Permanent changes in the current gain of the transistors due to gamma ray and fast neutrons were observed. In general, this damage accumulated more rapidly in the thick-base transistor than in the thin-base variety. This damage was accumulated in a range of 10^{10} nvt to 10^{14} nvt for neutrons above cadmium cutoff and from 10^7 r to 10^8 r for fission product gamma rays.

4. A considerable increase in the noise figure of transistors was observed immediately upon their exposure to gamma radiation. The increase in noise was observed to be proportional to the gamma flux.

BSR-4

Burnett J
NUCLEAR IRRADIATION OF ELECTRON TUBES - ELECTRON TUBE TYPES 5903, 5907, AND 5908,
Bendix Systems Division, Bendix Corp., Ann Arbor, Mich., Contract No. AF33(600)-35026, August (1958), 13 pp.

The electron tubes were irradiated in a nuclear reactor environment for a period of 19 days. The tubes were exposed passively. Tests before and after exposure showed no change in the essential characteristics.

D5-2880

Hicks D A, et al.
RADIATION DAMAGE TO TRANSISTORS,
Boeing Airplane Co., Seattle 24, Wash., Contract No. AF33(600)-35030, December 1, 1958, 13 pp. (plus many graphs).

Studies of the radiation damage to 23 transistor types have been carried out utilizing the Los Alamos critical assembly (Godiva II), the Materials Testing Reactor, and the University of Washington cyclotron. The transistor types included all power and frequency ranges for both silicon and germanium transistors. Neutron dosimetry was performed at each site, and all transistors were pedigreed before and after irradiation by the Philco Transistor Laboratory.

Plots are given showing the changes in the $1/\beta$ vs I_e curves, and the I_{co} vs temperature curves, as a function of the number of neutrons received per square centimeter. In addition, the collector characteristics are given in the low emitter current region for several neutron fluxes.

The damage constant (K) for each transistor type was determined. The average values are $(4.2 \pm 0.2) \times 10^{13}$ nvt--μsec for P-base germanium, $(3.1 \pm 0.4) \times 10^{12}$ nvt--μsec for N-base silicon, and $(4.6 \pm 3.3) \times 10^{12}$ nvt--μsec for P-base silicon. Larger K indicates smaller susceptibility to permanent radiation damage.

This report is concerned with permanent damage effects; the program will continue as new devices become available. Superimposed upon this problem is that of transient damage. The entire circuit is concerned in this case--the effect is certainly not limited to transistors. Because the relative importance of these temporary effects depends critically upon the circuit involved, the testing of prototype circuits is commencing at Boeing and at other laboratories.

DOFL-TR-452 AD-128157

Behrens W V and Shaull J M
THE EFFECTS OF SHORT DURATION NEUTRON RADIATION ON SEMICONDUCTOR DEVICES,
Diamond Ordnance Fuze Laboratories, Washington, D. C., April 10, 1957, 20 pp. (refs).

Transistors, semiconductor diodes, and solid-electrolyte batteries were exposed to short duration, high intensity neutron radiation from a U^{235} critical assembly which was primarily a neutron source. The effect on these components was ascertained by comparing their principal parameters before and after exposure, and in several cases operating units of equipment utilizing these components were monitored during irradiation.

The degree of damage to different semiconductor devices from exposure to the same level of neutron radiation varied considerably.

ECP-2

ENVIRONMENTAL REQUIREMENTS GUIDE FOR ELECTRONIC COMPONENT PARTS,
Office of the Director of Defense Research and Engineering, Washington 25, D. C.,
May (1959), 11 pp.

The purpose of this document is to promote a guide for environmental design requirements for use in planning current and future research and development programs involving electronic component parts.

EM-0856-1

Robinson Charles C
NUCLEAR EFFECTS ON ELECTRONIC COMPONENTS,
Electrical Manufacturing, Vol. 58, pp. 96-99, 268, 270, 272, August (1956).

What goes on when a wire-wound or deposited-carbon resistor, phototube, transistor or a diode becomes exposed to gamma rays or other forms of nuclear radiation? It is still too early to provide much precise tabular or chart data, but the Air Force, for one, is engaged in an exhaustive program. In this article, this program is discussed; the meaning and importance of nuclear effects on components are analyzed; and some preliminary appraisals of the behavior of certain components are given.

FZM-715A

PULSED NUCLEAR RADIATION TESTING OF ELECTRONIC SYSTEMS,
Engineering Department, Convair, Division of General Dynamics Corporation, Fort Worth,
Tex., April (1957), 25 pp. (3 refs).

Studies have indicated that a reactor based upon the BORAX type may be readily adapted for electronic system pulse-radiation testing requiring fast-neutron fluxes greater than 10^{15} n/cm^2/sec and integrated fluxes per pulse greater than 10^{13} nvt. Advantages of utilizing this type of reactor are, in addition to high fluxes and high dosages per pulse, that the basic reactor development has already been accomplished, and that the reactor and facility can be built at a moderate cost in a short period of time. Such a reactor and associated testing facility are described in this report.

At a remote location, the reactor and facility can be in operation in roughly 16 months and will cost approximately $760,000. At a nonremote location where containment will have to be provided, it can be in operation in 22 months at a cost of approximately $1,400,000. A test laboratory and equipment can be added to either location for about $600,000.

FZM-915

Miglicco P S
RADIATION EFFECTS ON ELECTRONIC COMPONENTS,
Convair, Division of General Dynamics Corporation, Fort Worth, Tex., May 1, 1957, 41 pp.

A systematic program is being carried out to determine the effects of radiation on the electrical properties of electronic components. As part of this program, data were

obtained for a number of crystal diodes, capacitors, resistors, gas-filled tubes, thermistors, high voltage batteries, the Ektron cell, and photomultipliers. The electrical properties of the components were monitored before, during, and after the irradiation. Two of the crystal diodes, all the capacitors, two types of resistors, the Ektron cell, and the photomultipliers showed significant changes of property both during and after irradiation. Results are presented for each type of component irradiated.

GA-273

Van Lint Victor A J
TRANSIENT RADIATION EFFECTS,
General Atomic Division of General Dynamics Corporation, San Diego, Calif., January 10, 1958, 21 pp.

This is a report covering the fundamentals of radiation damage and the needs for dosimetry. Experimental work was performed on resistors, capacitors, gas-filled ion chambers, and P-N junction diodes. Future experiments are outlined.

GE-57-GL-205

Langdon W R and Richardson S C
PROBLEMS ASSOCIATED WITH RADIATION TESTING OF TRANSFORMERS IN HIGH AMBIENT TEMPERATURES,
General Engineering Laboratory, General Electric Co., Schenectady, N.Y., Contract No. AF33(616)-3623, May (1957), 12 pp.

Some of the problems associated with radiation testing of small transformers in 500°C ambient temperatures are discussed. These problems include: general requirements for radiation testing, oven design and construction, space limitations, instrumentation, and the need for careful preliminary testing.

GE-57-GL-206

Fraser J C
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC TRANSFORMERS AND TRANSFORMER MATERIALS IN HIGH AMBIENT TEMPERATURES,
General Electric Co., Schenectady, N.Y., May (1957), 12 pp.

The General Engineering Laboratory of the General Electric Company is undertaking the testing of transformers and transformer materials in the Brookhaven National Laboratory's graphite reactor. Three separate tests have been carried on in an ambient temperature of 500°C. The first of these was designed to test the radiation tolerance of materials; the other two tested actual transformers.

This paper describes the materials and components tested, test procedures, and discusses the data obtained. Curves are presented showing the radiation-temperature effects noted, and the test results are summarized.

GE-57-GL-255

Thorson J W
THE EFFECTS OF REACTOR RADIATION ON GERMANIUM AND SILICON DIODES,
General Engineering Laboratory, General Electric Co., Schenectady, N.Y., July (1957), 62 pp.

The effects of reactor radiation on seven types of crystal diodes have been investigated. Irradiations for times ranging from 30 seconds to 2 hours have been carried out in a fast-neutron flux of 10^{11} nv in the Brookhaven National Laboratory graphite reactor. Data are presented in the form of oscillograms.

None of the diodes tested survived an integrated fast neutron dose of 3×10^{14} nvt. However, the effectiveness of small radiation doses in reducing reverse-recovery time suggests a new procedure for the production of computer diodes. More flexible circuit designs and improved manufacturing techniques can increase the radiation tolerances of semiconducting devices.

GNE-4 AD-125193

Metscher William, 1/Lt. (USAF)
IRRADIATION OF P-N JUNCTION DIODES,
Thesis, School of Engineering, The Air Force Institute of Technology, Air University, March (1957), 45 pp. (6 refs).

In an attempt to determine the effects of gamma radiation on germanium p-n junction diodes, the back characteristics of Type 1784 diodes were measured while they were exposed to a gamma intensity of 3.5×10^5 roentgens per hour from a cobalt-60 source. The electrical properties of germanium diodes are known to be structure sensitive. The relative changes produced in the body and surface as a result of gamma irradiation are a prime object of this report. Diodes with treated and untreated surfaces are used to gain information on the surface effects.

The study indicates that irradiation of untreated diodes was caused by an immediate increase in the back current due to photogeneration. When the radiation ceases, there is a large decrease in the back current due to the cessation of the photogeneration. The decrease was not equal to the initial increase. Cumulative effects, due to the introduction of lattice defects, were evidenced by a gradual increase in the back current during the irradiation period. The treated diodes showed a sharp decrease in back current above a critical voltage. This is interpreted as a reversible change in the surface film and indicates that the bulk properties were only slightly changed by gamma radiation.

HAC-1

Wiser Herbert L
REPORT ON FIRST EXPERIMENT ON RADIATION EFFECTS ON SEMICONDUCTOR DIODES,
Research Laboratories, Hughes Aircraft Co., Culver City, Calif., February 15, 1957, 6 pp. (curves).

The purpose of this experiment was to study gamma radiation rate effects (as distinguished from total dose effects) on silicon and germanium diodes and contributions to these effects by air ionization collection currents.

Silicon (H-6008) and germanium (H-1N67A) diodes were placed in gamma radiation fields of 10^5 to 3×10^6 r/hr at the MTR Gamma Facility the week of November 26, 1956.

The collection on bare diode leads of ions and electrons formed in the ionization of air molecules by the radiation gave currents one or two orders of magnitude larger than the currents created inside the diode envelope. Insulation virtually eliminated this current source.

The most important result of this experiment, of immediate concern to the electronic designer designing for radiation environments, is the necessity for complete insulation of conducting surfaces of terminals, especially where potential differences exist between such surfaces. The ionized air molecules, ionized by radiation, must not be collected by conducting elements in low current (microamperes or less) or delicately balanced circuits.

HAC-2

Wiser Herbert L and Petroff Michael D
SECOND EXPERIMENT ON RADIATION EFFECTS ON SEMICONDUCTOR DIODES, Research Laboratories, Hughes Aircraft Co., Culver City, Calif., April 2, 1957, 8 pp. (curves).

This experiment was a continuation of the study of gamma radiation rate effects on silicon and germanium diodes. A number of diodes were also exposed to a dose of 4.5×10^7 r as a preliminary investigation of the permanent changes following moderate total doses.

This experiment was performed in a radiation field furnished by four MTR spent fuel elements at the MTR Gamma Facility the week of January 28, 1957.

HAC-3

Denney J M
PULSED NEUTRON IRRADIATION OF ELECTRONIC COMPONENTS, Technical Memorandum No. 522, Research Laboratories, Hughes Aircraft Co., Culver City, Calif., July 16, 1958, 29 pp.

Electronic components exposed to the Godiva II radiation pulse included resistors, capacitors, semiconductors, diodes, vacuum and gas tubes. Components were exposed to a maximum rate of 10^{16} n/cm^2/sec, to a total flux of approximately 10^{12} n/cm^2, and a gamma dose of approximately 300 rad. Transients, produced in open cables, the best capacitors, and in the transistors, all exhibited the same pulse shape and agreed with Godiva II radiation pulse shapes previously obtained by LASL.

Test circuitry supplied voltage to a component from equipment near the exposure site. A signal voltage was produced across a resistor in series with the test component, and fed to a bank of cathode followers driving long coaxial cables to the control site. The output from these cables was displayed and photographed on oscilloscopes. The maximum signal produced in the telemetry system alone during the neutron pulse was 0.1 volt; component signal measurements were corrected appropriately.

The magnitude and polarity of voltage pulses produced in the cables and measuring equipment varied with termination resistance and applied voltage. Carbon resistors, 10-K ohms and in 1/2-watt and 2-watt sizes, indicated voltage pulses of 0.10 and 0.05 volt, respectively. Mica, ceramic, paper, electrolytic, and tantalum oxide capacitors from 0.001 to 1 microfarad indicated voltage pulses up to 0.5 volt. Subminiature vacuum tubes, a pentode Type 5702 and a triode Type 5703, used in single-stage amplifier circuits, showed increased conduction during the Godiva burst. A Type 5643 subminiature thyratron biased at -2 volts and a Type OB-2 glow discharge tube biased at +110 volts (both normally nonconducting under these circumstances) conducted during the Godiva burst.

A silicon HD-6008, a germanium 1N67A, a silicon 904, and a germanium 2N395 exhibited transients during the pulse.

HAC-4

Wiser H L and Petroff M D
THIRD EXPERIMENT ON RADIATION EFFECTS ON SEMICONDUCTOR DIODES,
Research Laboratories, Hughes Aircraft Co., Culver City, Calif., May 29, 1957, 10 pp. (curves).

A continuation of the study of the effects of gamma radiation on silicon diodes, this experiment was designed to check the large difference between the rate effects on thin wafer and thick wafer diodes as observed in the first and second experiments. A part of this experiment was devoted to determining the uniformity and energy spectrum of the gamma flux in the spent fuel element radiation air column at the MTR Gamma Facility. Although it was not possible to realize all the modes of investigation suggested by the analysis of the results of Experiments I and II, the following additional studies were conducted:

1. Effect of a 1.5×10^8 r dose on the reverse and forward characteristics of silicon diodes 6001, 6002, 6003, 6005, 6006, 6007, 1N625, 1N629.

2. Dependence of rate effect on dose.

3. Zero-current voltage dependence on the radiation intensity.

4. Radiation rate effect on the reverse current of quick-recovery diodes, 1N625 and 1N629.

5. Effect of temperature on the radiation rate effects.

HAC-5

Perkins C W, et al.
FIRST EXPERIMENT ON THE EFFECTS OF RADIATION PULSES ON ELECTRONIC CIRCUITS AND COMPONENTS,
Physics Laboratory, Hughes Aircraft Co., Culver City, Calif., February 3, 1958, 42 pp.

This report describes tests of the transient performance of electronic circuits and components during exposure to bursts of gamma radiation. The over-all experiment was designed to show the voltage, current, and change of component value which occur during radiation and the effects of these upon simple circuits. Changes of this type have been given little attention, although they may lead to malfunction of equipment when exposed to high radiation rates. The maximum dose was 26 rep/pulse, and in no case was this amount of radiation sufficient to produce observable, permanent changes in the samples under test.

Equipment was so designed that component and circuit samples could be exposed to gamma radiation bursts obtained when high energy electrons produced by a linear accelerator strike a heavy metal target. Individual components, selected for frequency of use and sensitivity to radiation, were tested by presenting radiation-induced current and voltage pulses on an oscilloscope where they were recorded photographically. Sample circuits, such as single tube amplifiers and multivibrators were tested by presenting pulses appearing at their output terminals on the oscilloscope. The radiation bursts

averaged 2.6 x 10^6 r/sec for 10 μsec for the component samples, and 2.8 x 10^5 r/sec for 10 μsec for the circuit samples.

Experimental results are presented on resistors, printed circuit boards, condensers, diodes, amplifiers, and electronic circuits.

HRB-96-R-3

Laughlin Robert D and Riddle Robert L
IRRADIATION OF TRANSISTORS IN A THERMAL FISSION REACTOR SPECTRUM,
Haller, Raymond, and Brown, Inc., State College, Pa., April 19, 1957, 35 pp.

This report discusses three basic topics: dynamic measurements on transistors in a radiation field (experiment 1 and 2), and a tape irradiation experiment.

Several conclusions drawn from transistor experiment 1 are that the effect of fission spectrum irradiation upon semiconductor devices has essentially three effects: (1) transient effects due to flux density and gamma heating; (2) semipermanent effects due to integrated flux; and (3) permanent effects due to integrated flux after annealing.

The conclusions drawn from experiment 2 are as follows: There is a noise effect which is present when the devices are in a flux field above that which is produced by integrated flux. There is an annealing effect present after irradiation which, in general, tends to improve the operation; however, the short-circuit current gain tends to remain at a constant level or degrades slightly during the annealing period.

Tentative limits for flux density and total integrated flux may be chosen as follows: For no appreciable degradation in the operation of a transistorized crystal-video receiver, a flux density of 10^8 nv and an integrated flux of 10^{13} nvt are acceptable. There are several questions that these experiments have raised, but have not answered. Why does the noise level of the 2N112 types in the presence of flux increase more rapidly than that of surface barrier units? Why does the damage appear to be larger in certain circuits than in others? What is the relative effect of fast neutron flux to slow neutron flux and what is the contribution of the gamma flux?

From the magnetic tape tests, there was no essential change in the signals and noise or signal-to-noise ratio as measured. At the beginning of the tests, it was suspected that some erasing of the tapes would take place due to a disordering of the magnetic domains by nuclear bombardment or perhaps by gamma heating, but this did not prove to be the case. It was therefore concluded that information, both pulse and sinusoidal, stored on magnetic tape is insensitive to the effects of combined neutrons and gamma radiation up to an integrated dose of approximately 10^{16} nvt for neutrons and 2.83 x 10^6 R for fission gamma rays, when measured under the conditions stated in the experiment. A test of the damage to the base material of the tape has not yet been made and some stretching may be possible, but several reruns on the playback machine have shown no gross damage to the tape other than the fracture of spools on which the tape was stored.

IBM-1

Bohan W A, et al.
SEMICONDUCTOR DEVICE OPERATION IN A PULSED NUCLEAR ENVIRONMENT,
International Business Machines Corporation, Oswego, N.Y. Presented at the National Telemetering Conference, May 25-27, 1959, 7 pp. (17 refs).

Early work on the effects of nuclear radiation in bulk semiconductor materials indicated that problems should be expected if semiconductor devices were operated in a nuclear environment. Recent work in many laboratories has succeeded in quantitatively correlating these effects in manufactured devices. The basis for the majority of these investigations has been, however, the environment which could be expected to exist in the vicinity of a conventional nuclear reactor. In contrast, the work reported in this paper was primarily concerned with the effects of very high dose rate nuclear radiation. The radiation was delivered in single pulses, about 200 microseconds wide, with accompanying maximum rates of 10^{16} n/cm^2/sec and 10^7 roentgen (gamma)/sec. Data were collected before, during, and after each radiation pulse.

The source of radiation used in these experiments was the Godiva-II assembly of the Los Alamos Scientific Laboratory (LASL). This device is a fully enriched, bare U^{235} assembly, capable of prompt critical operation. When the device is pulsed, the fission chain reaction builds up very rapidly, until the expansion due to total energy release makes it subcritical. During a typical pulse, a sample placed in the maximum dose region receives of the order of 10^{12} n/cm^2 and 10^3 gamma-rad (tissue) in a period of about 200 microseconds.

The various experimental and analytical investigations upon which this paper was based have resulted in the following conclusions:

1. In semiconductor materials and devices exposed in the Godiva environment, the ionization is predominantly gamma-ray-produced and the lattice defects neutron-produced.

2. The agreement between a_{cb}/a_{cbo} vs integrated flux curves obtained statically and as a function of integrated flux during the burst indicates strongly that there is little or no rate dependence in permanent bulk damage.

IBM-2

Bohan W A
EFFECTS OF PULSED X-RAY RADIATION ON SEMICONDUCTOR DEVICES,
International Business Machines Corporation, Federal Systems Division, Oswego, N.Y., 13 pp. (5 refs).

A series of experiments has been performed to determine the effects of high dose rate X-radiation on transistors. The radiation source used was the Bremsstrahlung (X-radiation), produced from stopping electrons in a target material. The electrons were provided by a 6-Mev linear accelerator and a 3.5-Mev resonant transformer accelerator.

IBM-3

Boczar P G, et al.
SOME EFFECTS OF PULSED RADIATION ON ELECTRONIC COMPONENTS - III. RESULTS OF JANUARY 1959 GODIVA TEST SERIES,
International Business Machines Corporation, Federal Systems Division, Oswego, N.Y., 38 pp. (10 refs).

A series of experiments was performed at the Los Alamos Scientific Laboratory on January 28-29, 1959, using the Godiva prompt critical assembly. These experiments

were part of the series being conducted by IBM Oswego to determine the effects of pulsed radiation on electronic components.

During the 2-day test period, approximately 75 components were exposed during eight Godiva bursts. Components tested were resistors, vacuum tube diodes, capacitors, transistors, thyratrons, voltage regulator tubes, and a quartz crystal oscillator. The results of this test series were most significant in two areas:

1. Transient effects produced by ionization,
2. Confirmation of theories on permanent damage to transistors.

ITR-1193 X-8702

THE EFFECTS OF A NUCLEAR EXPLOSION ON COMMERCIAL COMMUNICATIONS EQUIPMENT - OPERATION TEAPOT - NEVADA TEST SITE, FEBRUARY TO MAY 1955, Federal Civil Defense Administration, Battle Creek, Mich., 66 pp. (6 refs).

Atomic-blast exposure tests on commercial communications equipment were conducted during Operation Teapot, Apple II shot. These tests were made to provide Civil Defense planners with data for qualitative predictions of the probable survival range, the extent of damage, and nature of repairs required to restore communication service after a blast. Approximately 150 widely diversified units of communications equipment (mainly electronic, but including sirens) were exposed, under the sponsorship of the Radio-Electronics-Television Manufacturers Association (RETMA), two siren manufacturers, and the Federal Civil Defense Administration (FCDA). Exposed items were in or near groups of structures located at approximately 4700 and 10,500 feet from ground zero. Where possible, identical products were exposed at these two locations, so that one set of items would be subjected to moderately severe damage and the other set to light damage. Tests showed that commercial communications equipment was generally more resistant to nuclear explosion damage than the structures in and near which the products were exposed. Additions concerning communications equipment were proposed to supplement FCDA published statements concerning "Blast Damage from Nuclear Weapons of Larger Sizes."

JAP-0158

Loferski J J
ANALYSIS OF THE EFFECTS OF NUCLEAR RADIATION ON TRANSISTORS, Journal of Applied Physics, Vol. 29, No. 1, pp. 35-40, January (1958).

In this paper the behavior of transistors in nuclear radiation fields is discussed on the basis of the existing knowledge of the interaction between semiconductors and such radiation. This paper is concerned only with permanent changes, i.e., changes which remain after irradiation has ceased. Therefore, radiation-induced ionization and the noise which accompanies it are excluded. In Part II, the available information on the effect of β and γ rays and fast and slow neutron irradiation on semiconductors is reviewed. In Part III, these results are combined with transistor theory to predict the behavior of these devices in radiation fields. This report concentrates particularly on the amplification factor of the transistor and emphasize its behavior in the fast neutron field of a reactor. In Part IV, theory is compared with experimental data. Although the discussion is confined to Ge transistors, much of the analysis is applicable to transistors made from other materials.

JAP-0358

Fonger W H, Loferski J J and Rappaport P
RADIATION INDUCED NOISE IN P-N JUNCTIONS,
Journal of Applied Physics, Vol. 29, No. 3, pp.588-591, March (1958),(8 refs).

Fast particles passing through a semiconductor commonly generate, either directly or through their fast secondaries, many electron-hole pairs. If these pairs are generated within a diffusion length of a p-n junction, their subsequent dissociations at the junction produce observable voltages and/or currents. This phenomenon is called the electron-voltaic effect, photovoltaic effect, etc., according to the nature of the primary fast particles. The effect has been widely studied in connection with photo-cells, light batteries, β-ray batteries, phototransistors, etc.

This paper discusses the noise aspects of the voltaic effect. The basic building block of the phenomenon is the burst of pairs generated by a single primary particle, and the noise is conveniently discussed in terms of this basic event. The theory of the noise is discussed, diode measurements are discussed and data given, and three applications of this noise are discussed.

JAP-0459-1

Alley R E, Jr.
IN-PILE MEASUREMENTS OF RADIATION IN MAGNETIC MATERIALS,
Journal of Applied Physics, Vol. 30, No. 4, April (1959), 2 pp. (5 refs).

Experiments have been performed at Brookhaven National Laboratory to determine the effects of nuclear reactor radiation upon the characteristics of ferrites and metallic magnetic materials. Photographs of 60-cycle hysteresis loops and bridge measurements of 1000-cycle inductance were made before irradiation, periodically during irradiation, and after reactor shutdown. The samples were irradiated for 12 days, resulting in an integrated fast flux of 1.6×10^{17} n/cm^2.

No permanent effects were observed in any ferrite. In-pile changes in ferrite properties are identified with changes due to temperature variations resulting from gamma-ray absorption.

Permanent damage was observed in all metallic samples tested. Supermendur and Deltamax were least affected, showing increases of the order of 50% in coercive force and small decreases in initial permeability. Various samples of 4-79 Mo-Permalloy were affected differently, but all showed change in shape of hysteresis loop, several hundred percent increase in coercive force, and about 80% decrease in initial permeability. Supermalloy was most damaged by radiation, showing marked effects after 24 hours, and progressively greater effects throughout the exposure period.

JAP-0557-2

Wittels M C and Sherrill F A
FAST NEUTRON EFFECTS IN TETRAGONAL BARIUM TITANATE,
Journal of Applied Physics, Vol. 28, No. 5, pp. 606-609, May (1957), (10 refs).

Tetragonal $BaTiO_2$ is transformed into cubic $BaTiO_3$ as a result of irradiation with fast neutrons at a temperature of approximately 100°C. Sufficient atomic displacements are

produced by bombardment with an integrated fast neutron flux of 1.8×10^{20} n/cm^2 so that tetragonal single crystals (c_o = 4.0349A and a_o = 3.9923A) expand anisotropically to form perovskite-type cubic single crystals with a_o = 4.0824A. The irradiated material remains cubic to the lowest temperature of measurement, 78°K, showing none of the low temperature phase transitions of unirradiated $BaTiO_2$, and after annealing at 1000°C, the crystal remains cubic but with a reduced lattice parameter. X-ray, thermal, and optical methods were employed in studying these effects.

JCP-0458-1

Kommandeur J and Schneider W G
PHOTOCONDUCTIVITY OF ANTHRACENE - V. EFFECT OF IMPERFECTIONS ON THE BULK PHOTOCURRENT,
The Journal of Chemical Physics, Vol. 28, No. 4, pp. 590-595, April (1958), (7 refs).

Bulk photocurrents of anthracene have been measured on crystals of high purity, scintillation crystals, and crystals irradiated with thermal neutrons. It is found that the source and treatment of the crystals strongly affects the spectral response and the voltage and intensity dependence of the bulk photocurrent. This can be related to the density of the imperfections in the crystals. Direct evidence for the existence of traps was furnished by the electrical analog of the thermoluminescent glow curves and by the increase of the photocurrents with red radiation.

JCP-0458-2

Compton D M J, et al.
PHOTOCONDUCTIVITY OF ANTHRACENE. THE EFFECT OF NEUTRON BOMBARDMENT,
The Journal of Chemical Physics, Vol. 28, No. 4., pp. 741-742, April (1958), (2 refs).

Neutron bombardment is known to modify the properties of many insulators. It was therefore felt that a study of the effect of neutron bombardment on the photoconductivity of anthracene might help to clarify the mechanisms involved. A series of measurements of photoconductivity and other properties was made on anthracene crystals before and after bombardment in the neutron flux of the pile at Chalk River. It was found necessary to carry out the bombardment in an atmosphere of helium to avoid surface oxidation. No radioactivity was found after removal from the pile. A summary of the more striking results is given.

KAPL-1301

Tucker C W, Jr. and Senio P
SOME FACTORS IN THE RESISTANCE OF CRYSTALS TO RADIATION DAMAGE,
Knolls Atomic Power Laboratory, Schenectady, N. Y., Contract No. W-31-109-Eng-52, March 24, 1955, 8 pp. (4 refs).

X-ray diffraction studies of radiation damage in ionic, covalent, and metallic crystals are beginning to reveal some of the factors which appear to be important in determining the radiation stability of a given material. These factors are homogeneity of damage, particle size, cleavage or fracture, strength, grain boundaries, temperature, and bond type. While evidence is not yet complete to prove the importance and to understand all of these factors, the basis is presented for their apparent relevance. It is hoped that the work will provide a basis for discussion of irradiation effects and for further, more systematic studies.

KAPL-1724

Wachspress E L
A GENERALIZED TWO-SPACE-DIMENSION MULTIGROUP CODING FOR THE IBM-704,
General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, April 30, 1957, 132 pp. (7 refs).

A detailed description of a generalized two-space-dimension multigroup calculation for the IBM-704 is given. Basic theory, input and output format, a guide to the flowcharts, tape movements, and operational procedure are included in the discussion.

KAPL-1742

Smith W A, Jr., Noonan J E and Minassian K
SUMMARY OF FAST NEUTRON IRRADIATION STUDIES ON GERMANIUM,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, April 26, 1957, 35 pp. (9 refs).

A summary is given of studies made at KAPL to determine the energy dependence of fast neutron effects on the electrical properties of germanium. Irradiations were made by using neutrons produced in positive ion reactions. A nonlinear relationship between neutron energy and the number of interstitial atoms produced per neutron is indicated for the energy range 0.7 to 4.8 Mev.

Material preparation techniques are discussed and methods of determining neutron response characteristics of germanium materials for dosimetry applications are presented.

LA-2152

Glare James Paul
EQUIPMENT FOR EXPERIMENTS WITH ACTIVITIES HAVING HALF-LIVES IN THE RANGE FROM 10 MICROSECONDS TO 1 SECOND,
Los Alamos Scientific Laboratory, Los Alamos, N.M., Contract No. W-7405-Eng-36, September (1957), 31 pp. (3 refs).

The electronic circuits described were built for conducting experiments with radioactivities having half-lives of 10 microsec to 1 sec range. The Model 10 Beam Shim Pulser was designed for pulsing the beam of an electrostatic generator. It produces +550 volt pulses with rise and fall times of 1 microsec and an adjustable pulse length of 10 microsec to 1 sec into a capacitive load of 100 micromicrofarads. The Model 10 10-Channel Time Delay Analyzer has channel widths of 10 microsec to 1 sec and was built for determining half-lives of radioactivities in this time range. The Model 1 Delay and Gating Circuit is used with a 100-channel pulse height analyzer to turn it on and off with a 1 microsec accuracy. The Model 2A Gating Unit incorporates delayed coincidence circuits which control the operation of the analyzer.

LAC-NR-51 (Vol. 1)-2

Bridges W L
RADIATION EFFECTS TESTING OF AIRCRAFT SUBSYSTEMS AND COMPONENTS AT AIR FORCE PLANT NO. 67 FOR THE ANP PROGRAM,
Lockheed Nuclear Products, Lockheed Aircraft Corporation, Georgia Division. Paper presented

at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 5 pp.

A few of the features of Air Force Plant No. 67 are briefly reviewed as they contribute to a discussion of the philosophy of radiation effects testing of aircraft subsystems and components.

The major functions of this facility will be to irradiate, test, and evaluate aircraft components and complete subsystems under dynamic environmental conditions. To accomplish these functions, some rather specific requirements must be satisfied. The first is to provide for dynamic testing of aircraft subsystems and components in realistic radiation fields; that is, in fluxes comparable to, and in some cases in excess of, those expected to fall on the particular system at its most likely location in a nuclear-powered aircraft. The second requirement is the ability to handle large test articles rapidly. The third is for an adequate handling and testing capability.

Large test articles must be moved to and from the reactor safely with means provided for evaluating them before, during, and after irradiation without exposing personnel to excessive radioactivity.

LAC-NR-51 (Vol. 2)-20

Duncan G I, Fraser J C and Valachovic B
THE EFFECTS OF NUCLEAR RADIATION ON SPARK GAPS,
General Electric Co. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 18 pp.

The General Electric Company has completed a program covering the testing of spark gaps in the Brookhaven National Laboratory's graphite reactor. It consisted of a two-week in-pile exposure designed to investigate the voltage breakdown strength of air at various pressures in the presence of the following radiation levels:

Fast flux: 1×10^{11} fast neutrons/cm^2-sec

Thermal flux: 2×10^{12} thermal neutrons/cm^2-sec

Gamma flux: 1×10^{12} gamma photons/cm^2-sec

This paper describes the components tested, the test equipment and circuitry, the dynamic pressure system used, and discusses the data obtained. Curves are presented showing the effects noted, and the results of the tests are summarized. This paper covers work performed under Contract No. AF33(616)-5579.

LAC-NR-51 (Vol. 2)-21

Van Houten G R, O'Nan T C and Hood J T
RADIATION TESTING AND PROPERTIES OF A BORON NITRIDE DIELECTRIC CAPACITOR,
P. R. Mallory and Co., Indianapolis, Ind. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Ga., October 28-30, 1958, 34 pp. (5 refs).

Tests to date include:

1. Study of boron nitride powders and compacts in a reactor environment.

2. Fabrication and testing of capacitor bodies from reactor irradiated boron nitride.
3. Operational testing of boron nitride capacitors in a high gamma environment.

Results to date include:

1. Good experimental verification of theoretical calculations.
2. Boron nitride is definitely a preferred material for high temperature dielectric applications.
3. Boron nitride dielectric capacitors which are constructed to be self (neutron) shielding retain normal physical properties during and after irradiation.
4. Instantaneously gamma-induced current leakage, as expected, varies as the square root of the gamma photon density. Such leakage can be appreciable at high voltage gradients.
5. Gamma scattering and capture causes local heating in proportion to the gamma photon density and energy. This gamma heating may increase the dielectric temperature enough to cause appreciably increased current leakage.
6. As a result of direct and indirect gamma induced leakage, limited gamma shielding may be necessary for high voltage units or for very large uncooled units. Similar problems with other dielectrics would generally be of even greater magnitude.

LAC-NR-51 (Vol. 3)-22 FZM-1159

Brown V C and Peterson N M
PREDICTING THE PERFORMANCE OF IRRADIATED ELECTRONICS SYSTEMS BY SIMULATION ON THE ANALOG COMPUTER,
Convair, Division of General Dynamics Corporation, Fort Worth, Tex. Paper presented at the 3rd Semi-Annual Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 15 pp.

The method of simulating electronics systems on analog computers for the purpose of studying the effects of radiation is described, and a comparison is made between the results obtained by the simulation technique and data obtained in an actual irradiation. The results show that, by combining proper statistical methods with computer simulation, the performance of electronics systems under radiation may be successfully predicted.

LAC-NR-51 (Vol. 3)-25

Gunson D O
RADIATION EFFECTS ON FLIGHT CONTROL SUBSYSTEM DESIGN,
Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 8 pp.

Successful application of nuclear propulsion to aircraft requires the development of a high performance flight control subsystem that is not only more reliable, serviceable, and maintainable than the best flying today, but is at least as efficient while operating in a radiation environment. The attainment of these aims demands close and continued cooperation between the radiation effects specialist and controls designer throughout the design, development, and testing of this subsystem. The basic problems considered are: the establishment of the important characteristics of a flight control subsystem, how

radiation environment affects these characteristics, and the type of radiation effects data required by the controls designer.

LAC-NR-51 (Vol. 3)-30

Klein C A and Straub W D
ON THE ENERGY LEVELS IN NEUTRON-IRRADIATED P-TYPE SILICON,
Raytheon Manufacturing Company, Waltham, Mass. Paper presented at the 3rd Semi-Annual Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 21 pp.

High resistivity p-type silicon samples were irradiated in the Brookhaven pile for short periods of time resulting in integrated fast neutron fluxes of the order of a few $10^{14} n/cm^2$. Hall coefficient and conductivity measurements were then performed over extended temperature ranges. A detailed analytical investigation of these data provides evidence for at least two bombardment-induced hole trap levels in the lower half of the energy gap. The deep trap, at 0.29 ev from the valence band, is introduced at a rate which appears to be proportional to the integrated flux. Moreover, it has been established that for this level the product of the statistical weight factor by the temperature shift factor is practically equal to one. The shallow trap, at 0.16 ev from the valence band, is not yet as fully describable. The work is still in progress, and only the established results at the time of this writing (August 1958) are given here. The whole approach is of a "phenomenological" nature, in the sense that no attempts were made to correlate the presently available data with possible types of defects or defect models.

LAC-NR-51 (Vol. 3)-33

Salkovitz E I, Schindler A I and Ansell G S
THE EFFECT OF NUCLEAR IRRADIATION ON METALLIC AND NONMETALLIC MAGNETIC MATERIALS,
Naval Research Laboratory, Washington, D. C. Paper presented at the 3rd Semi-Annual Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 23 pp. (2 refs).

Extensive investigations of the effects of nuclear environments upon magnetic materials have been undertaken. A major aim of the program is to obtain basic information concerning the mechanisms producing the observed effects. More than 100 samples have been irradiated in the Brookhaven graphite reactor at an integrated flux of 10^{17} nvt. The materials studied have been in the form of toroids or rods, and have consisted mainly of various ferrites and square loop and high permeability alloys. In addition, discs of permanent magnet-type ferrites and portions of magnetic devices have been irradiated. A detailed discussion will be given of the method of canning temperature control, and the means by which pre- and post-irradiation magnetic measurements were made.

LAC-NR-51 (Vol. 4)-37

Pfaff E R and Shelton R D
THE EFFECTS OF RADIATION ON VARIOUS RESISTOR TYPES,
Admiral Corporation, Chicago, Ill. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 13 pp.

A study of the effect of nuclear radiation on various types of resistors revealed interesting trends and several possible damage mechanisms, most of which seem to be associated with the boron content in the components. Film-type resistors, consisting of a glass core containing boron and a conducting film with no boron, showed greater damage when the film was thin (high resistance values). It is probable that in this case the (n, a) reaction in boron removed some of the atoms from the thin conducting film.

Resistors having a core with no boron but with a boro-carbon conducting film showed greater damage when the film was thick (low resistance values). It is conjectured that since, in this case, all of the boron is in the conducting film, there is more recoil energy deposited in the conducting layer having the thicker film.

Wire-wound resistors having a vitreous enamel coating had resistance changes greater than could be attributed to temperature coefficient or a change from a disordered to ordered arrangement in the wire. There is some evidence that the vitreous coating, sometimes containing a large amount of boron, changes density sufficiently to distort the wire and increase the resistance of the unit by as much as 6%.

LAC-NR-51(Vol. 4)-38

Aukerman L W and Willardson R K
RADIATION EFFECTS IN COMPOUND SEMICONDUCTORS,
Battelle Memorial Institute, Columbus, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 14 pp. (12 refs).

The properties of semiconductor devices (such as transistors and rectifiers) depend strongly on minority-carrier lifetime, carrier concentration, and mobility. These parameters are strongly affected by nuclear irradiation. For the design of a device relatively insensitive to radiation damage, semiconductors composed of heavy atoms and having a high minority-carrier mobility and a large energy gap are desirable. The properties of several compound semiconductors, including AlSb, InP, GaAs, CdTe, and InSb, are compared with respect to the above criteria. Investigations of the effects of fast-neutron irradiation on these compounds are reported. Annealing and heat-treatment studies before and after irradiation are discussed.

LAC-NR-51(Vol. 4)-39

Happ W W and Hawkins S R
A CRITICAL SURVEY OF RADIATION DAMAGE TO CIRCUITS,
Lockheed Aircraft Corporation, Palo Alto, Calif. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 35 pp. (8 refs).

A critical survey was undertaken to investigate factors affecting circuit performance in the presence of damage-producing radiations. Experimental work in progress consists of irradiating several types of circuits, such as multivibrators and blocking oscillators, by gamma radiation with a 100-curie cobalt-60 source. Causes of failure of the circuits tested thus far were traced primarily to the deterioration of semiconductor devices. This preliminary work is being used as a basis for planning investigations of other selected circuits, both under gamma and neutron irradiation.

LAC-NR-51(Vol. 4)-40

Hawkins S R and Happ W W
RADIATION STABILIZATION OF TRANSISTOR CIRCUITS BY ACTIVE FEEDBACK,
Lockheed Aircraft Corporation, Sunnyvale, Calif. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 21 pp. (16 refs).

The simultaneous deterioration of similar transistors due to radiation damage is employed to stabilize circuit characteristics by using one transistor as a feedback element. The relative merits of a number of circuit configurations are examined on the basis of over-all current and voltage amplification, battery requirements, transistor symmetry, and similar factors. The requirements of both stabilization and amplification are simultaneously satisfied for the common-emitter configuration using a transistor in the common-collector configuration as a feedback element. Design curves for this configuration are given for typical cases to illustrate the usefulness of this method of stabilization. Operating point stabilization is briefly discussed.

LAC-NR-51(Vol. 4)-41

Easley J W
COMPARISON OF NEUTRON DAMAGE IN GERMANIUM AND SILICON TRANSISTORS,
Bell Telephone Laboratories, Inc., Whippany, N. J. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 11 pp. (13 refs).

Quantitative comparison of the neutron bombardment sensitivity of germanium transistors to that of silicon transistors must include consideration of the mean time for minority carriers to traverse the base region of the structures being compared. Analysis shows that for transistors of comparable carrier-transport-factor frequency cutoff, germanium transistors should be capable of receiving fast-neutron exposures which are one to two orders of magnitude greater than those permissible for silicon devices before current-gain degradation becomes critical for typical circuit applications. Experimental data are presented for both germanium and silicon transistors which are in good agreement with the analysis.

LAC-NR-51(Vol. 4)-42

Denney J M, et al.
PULSED RADIATION EFFECTS IN SEMICONDUCTORS,
Hughes Aircraft Company, Culver City, Calif. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 1 p.

Typical semiconductors were exposed to pulsed neutron, electron, and gamma fluxes. The effects of these exposures on the electrical properties of the semiconductors was observed during the radiation pulse. These radiation effects are described and compared with analysis. Attention is given to some of the differences between transient and residual radiation effects in semiconductors.

LAC-NR-51(Vol. 4)-43

Huth Gerald C
THE EFFECT OF VARIATION OF THE WIDTH OF THE BASE REGION OF THE RADIATION TOLERANCE OF SILICON DIODES,
General Electric Co., Cincinnati, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corp., Marietta, Georgia, October 28-30, 1958, 7 pp. (8 refs).

Results are presented of experiments which were conducted to determine the effect of varying the width of the base region of a silicon diode on the radiation tolerance of the device as gauged by increase in voltage drop at forward bias. Reasonable agreement is shown between experimentally determined change in forward characteristic and behavior predicted from theoretical considerations--specifically considering the effect of degraded minority carrier lifetimes. Devices irradiated (40 in number) were of the alloy junction type based on the configuration of the General Electric IN-538 rectifier. Their over-all behavior is discussed including the near exponential increase found in forward voltage drop and the retention of reasonable reverse characteristics of all units during irradiation.

LAC-NR-51(Vol. 4)-44

Crittenden John R
THE EFFECT OF NUCLEAR RADIATION ON COMMERCIAL SILICON DIODES,
General Electric Co., Cincinnati 15, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 14 pp.

Several types of commercial silicon diodes were irradiated to 10^{16} nvt (En > 0.58 ev) in the Brookhaven Reactor at 25^{o} and 150^{o}C. The forward and reverse characteristics of each diode were photographed periodically from an oscillographic display during the irradiation period. Noise and switching time measurements were also accomplished. The results of this work indicate that electrically similar diodes vary in their response to nuclear radiation, and that the response to nuclear radiation is temperature dependent.

LAC-NR-51(Vol. 4)-45

Russell J A
EVALUATION OF SILICON DIODE IRRADIATION RESULTS IN TERMS OF MAGNETIC AMPLIFIER PERFORMANCE,
General Electric Co., Cincinnati 15, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 52 pp. (7 refs).

Three generic types of silicon diode failure under radiation are simulated. The simulation is applied to a full-wave, center-tap magnetic amplifier and a half-bridge, half-wave magnetic amplifier. Conclusions are drawn as to the most suitable basic diode type under radiation. Also discussed are: changes to be expected in magnetic amplifier performance as a result of radiation-induced diode effects; means of reducing some of these effects.

LAC-NR-51(Vol. 4)-46

Enslow G, et al.
GAMMA RADIATION EFFECTS IN SILICON SOLAR CELLS,
Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 37 pp. (16 refs).

Ten silicon solar cells were irradiated by a 100-curie Co^{60} gamma-ray source to a dose of 10^7 r. In-situ measurements of the open-circuit voltage and short-circuit current were obtained. Calculations to predict the performance of silicon solar cells under irradiation were made on the basis of known properties of silicon and on the basis of models of radiation damage in solids. Calculated and experimental results were compared. The electrical characteristics of the solar cells were measured as a function of temperature before and after irradiation. The performance of a silicon solar cell power supply in radiation fields is discussed.

LAC-NR-51(Vol. 4)-47

Gordon Frederick
THE EFFECTS OF NUCLEAR RADIATION ON POWER TRANSISTORS,
US Army Signal Research and Development Laboratory, Fort Monmouth, N.J. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 23 pp.

This paper presents the results of nuclear radiation experiments performed at Brookhaven National Laboratory to determine the effects of this radiation on power transistors of various types. A brief analysis of device parameter changes and of the evaluation of the results is presented. In addition, there is a short discussion of the interrelation between the minimizing of the effects of nuclear radiation on transistors and the specific application of the devices.

The device types that were exposed were homogeneous-base germanium power transistors. The device parameters that were monitored were small-signal and large-signal grounded-emitter current gain, as well as the reverse collector current. The techniques of measurement included multiple point measurements and curve tracer techniques. The results show fair agreement between experimental results and calculated values.

LAC-NR-51(Vol. 4)-48

Xavier M A
THE PERFORMANCE OF SOME ZENER REFERENCE ELEMENTS DURING EXPOSURE TO NUCLEAR RADIATION,
Cook Electric Company, Morton Grove, Ill. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 10 pp. (10 refs).

Sixteen Type IN429 and sixteen Type IN430B Zener reference elements were exposed to the radiation field of a nuclear reactor. This paper describes the measurement techniques and the corrections made to ensure accurate results required in dealing with the voltage reference elements. Irradiations were performed at epicadmium neutron flux levels of the order of 10^{11} nv_e until doses of up to 10^{15} nv_et were reached. The corresponding gamma dose rate was 2.1×10^6 roentgens per hour.

Detailed results are presented, and possible mechanisms of damage are described. The reference voltages of all the devices tested showed permanent decreases of up to 2.9%, although the average of the changes was in the order of 1-1/4%. The temporary damage was generally about 1/3%. The case temperature was monitored for one sample in each of the four irradiations.

During the past two years, there has been considerable activity in determining the effects of nuclear radiation on semiconductor electronic components. The emphasis has, however, been placed on transistors, and little information is available on other devices. This paper deals with the behavior of two types of Zener reference elements, which have found wide application as reference voltage sources because of their relative stability with temperature, small physical size, and mechanical ruggedness. At the time of the experiments, two types (1N429 and 1N430B by Hoffman Semiconductor) were generally considered as the best commercially available so the irradiations were performed on these types.

LAC-NR-51(Vol. 5)-55

Hansen J F and Shatzen M L
RADIATION EFFECTS ON ELECTRICAL INSULATION,
Battelle Memorial Institute, Columbus, Ohio, and Lockheed Aircraft Corporation. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Georgia, October 28-30, 1958, 11 pp.

Eight types of insulated, electrical wire were irradiated to a dose of about 1×10^{10} ergs/g(C) at temperatures of 15°, 55°, and 100°C, and relative humidities of 0 and 65% at each temperature in a cobalt-60 gamma source. Electrical resistance was measured before, during, and after irradiation; preirradiation and postirradiation breakdown voltage measurements were made, and the specimens were examined visually for signs of physical deterioration after irradiation.

All insulations exhibited a loss in initial resistance of at least 99% at one or more of the irradiation conditions. Serious deterioration of mechanical properties was observed for all except two polyethylene insulations. In general, best performance, from the standpoint of electrical properties, was obtained under cool, dry conditions. On the average, high temperature had a greater detrimental effect than high humidity. The temperature effect was most pronounced between 15° and 55°C.

For general-purpose use in a radiation field, under a variety of temperature and humidity conditions, polyethylene appears to be superior to the other materials studied. However, under specifically controlled temperatures and humidities, some of the other materials may be preferred.

LR-122 SA-402 3-4

Hart E J
LABORATORY INVESTIGATION OF SIX SA-402 EXPLOSIVE SWITCHES RETURNED FROM FIZEAU SHOT - OPERATION PLUMBBOB,
Sandia Corporation, Albuquerque, N.M., April 24, 1958, 8 pp.

This report discusses tests which were conducted to determine if there was any radiation or mechanical damage to the SA-402 switches by exposure to Fizeau Shot-Operation Plumbbob.

MLM-629

Ohmart P E, et al.
THE RADIOELECTRIC EFFECT,
Mound Laboratory, Contract No. AT-(33-1)-Gen-53, November 1, 1951, 36 pp. (10 refs).

An electrostatic field will exist between two materials having different work functions when the only connection between the materials is through a load impedance. If the two materials are connected externally by a current-measuring device and the separating medium is ionized by exposure to radiation, a current of electrons will flow in the external circuit from the material of lower work function to the material of higher work function. The quantity of this current depends upon the value of the external load impedance, the type and intensity of the incident radiation, the difference between the work functions of the electrode surfaces, the type and pressure of the separating gas, and the geometry of the setup.

Radiation measuring devices called "radioelectric cells" have been constructed on the basis of this "radioelectric effect." Gamma detecting cells have been developed which for specific uses offer marked advantages over conventional detectors. It is also possible to detect alpha, beta, and neutron radiation and to determine the difference between the work functions of two surfaces.

MM-56-113-21

Brown W L
NEUTRON RADIATION EFFECTS ON GERMANIUM TRÁNSISTORS AND SILICON DIODES,
May 11, 1956, 11 pp.

The work described in this report was performed in the interests of exploring the sensitivity of semiconductor devices to a neutron environment. The components tested were a group of germanium transistors and silicon diodes. The work was performed in the Brookhaven National Laboratory nuclear reactor.

N-0758

Fries R C
RADIATION-RESISTANT MOTORS FOR NUCLEAR AIRCRAFT CONTROLS,
General Electric Co. Published in Nucleonics, Vol. 16, No. 7, pp. 103-104, July (1958).

Results are given which indicate that electric motors stand up well to reactor radiation and high temperatures. Temperature damaged the motors more than limited exposure to neutrons and gamma rays. Radiation effects on the individual components and materials of the motors are discussed.

Na-0159-1

Allen K R and Phillips K
EFFECT OF RADIATION ON THE BREAKDOWN OF HOMOGENEOUS FIELD AND SPHERE GAPS,
Nature, Vol. 182, No. 4656, pp. 233-235, January 24, 1959, (3 refs).

This short paper gives a quantitative discussion of an investigation carried out to study the effect of radiation on the breakdown of homogeneous field and sphere gaps. The

electrodes were mounted in a glass chamber. Several air pressures were used in the spark gaps.

NAA-AD-148219 AD-148219

Eisen F H, et al.
RADIATION DAMAGE STUDIES IN COMPOUND SEMICONDUCTORS,
Atomics International, Box 309, Canoga Park, Calif., Contract No. AF33(616)-3924, (1957), 5 pp. (2 refs).

The objective of the work on this contract is to study the effects of electron irradiation on the III - V semiconductor compounds, utilizing changes in electrical properties, paramagnetic resonance absorption, and thermal conductivity. During this quarter, data have been obtained on the resistivity change of InSb after irradiation with 0.35 to 0.60 Mev electrons, and the Varian electron paramagnetic resonance (EPR) equipment has been received and put into operation.

NARF-56-27T-4 MR-N-122-4 X-21882

PROCEDURES FOR SYSTEM PANELS TEST NO. 2 - ADDENDUM 4,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, September 7, 1956, 115 pp.

System Panels Irradiation Test No. 2 was performed at Convair-Fort Worth during late 1956 and early 1957. In this test, existing aircraft systems mounted on test panels were irradiated, using the Ground Test Reactor as the source. The Ground Test Reactor was placed in the dry pool, and the panels to be irradiated were grouped around the reactor inside the pool. Measurements were made of the physical properties and operating characteristics of the panel before, during, and after irradiation.

This report is the fourth addendum to Procedures for Systems Panel Test No. 2 (Convair-Fort Worth Report MR-N-122). It describes the equipment to be furnished for this test by the Thompson Products, Inc., of Cleveland, Ohio, and Convair-Fort Worth, a Division of General Dynamics Corporation. Essentially, the equipment consists of a Power Plant Fuel Control System and a Capacitance Type Fuel Quantity Gage System, MIL-G-7817.

NARF-57-19T(Vol. 4)-4 X-21783

Easley J W
EFFECTS OF RADIATION ON SEMICONDUCTORS,
Bell Telephone Laboratories, Whippany, N. J. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 26 pp. (19 refs).

A brief survey of the effects of nuclear radiation on semiconductors of particular interest in device technology is presented in this paper. The known effects of nuclear radiation on the electrical properties of semiconductors are briefly reviewed to include the relative magnitude and qualitative differences between photon-, electron-, and neutron-induced alteration. Some of the principal aspects of the behavior of irradiated semiconductor devices are then qualitatively interpreted through inclusion of these

material properties in simplified device theory. The transistor current gain α is treated in some detail, and it is shown that the rate of increase of $(1 - \alpha)$ with bombardment is, for simple structures, inversely proportional to the α-cutoff frequency. Experimental data illustrating the analysis are presented.

NARF-57-19T(Vol. 4)-5 X-21783

Crittenden J R
THE GENERAL ELECTRIC ELECTRONICS COMPONENT TEST FOR SYSTEMS PANELS TEST NO. 2,
General Electric Co., ANPD, Cincinnati, Ohio. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 6 pp.

Three basic systems were exposed to medium level nuclear fluxes during Systems Panel Test No. 2. In each of the three systems tested, the effects of radiation were evident. The results of SPT No. 2 indicate that electronic amplifiers may experience some difficulty at approximately 10^{14} nvt epicadmium, that silicon diodes change radically for doses above 10^{12} nvt epicadmium, and the more sensitive parts of a television camera are the lens and pickup tube.

NARF-57-19T(Vol. 4)-6 X-21783

Clark J W .
DESIGN OF RADIATION SPECIFIED ELECTRONIC SYSTEMS,
Hughes Aircraft Co., Culver City, Calif. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 5 pp.

The design and manufacture of electronic systems for use in System 125A presupposes the ability to operate with nuclear radiation as an environmental specification. Components capable of meeting nuclear radiation specifications must be available to the system manufacturer. This in turn implies the presence of radiation facilities in which to carry on development of new radiation-resistant components and in which to carry on quality control testing during manufacture.

Some experimental investigations at Hughes Aircraft Co. will be described which indicate the importance of rate effects in system design and which point the direction toward component improvement. Present and planned radiation testing facilities at Hughes Aircraft Co. are specifically directed toward facilitating both development testing and quality control in connection with components and subsystems for System 125A. These facilities will be described.

NARF-57-19T(Vol. 4)-7 X-21783

Jacobs D L
EFFECT OF NUCLEAR RADIATION FROM THE GTR UPON CLOSED CIRCUIT TELEVISION EQUIPMENT,
Convair, Fort Worth, Texas. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 14 pp. (1 ref).

Closed circuit industrial television has been used for remote viewing in high radiation fields during systems tests and shielding studies. Television cameras have been exposed to integrated fast-neutron doses as high as 4.32×10^{14} n/cm^2 without detrimental effects

upon electronic components. Coloration of optics due to ionizing radiation (with resulting loss of transmission) occurs and is the limiting factor in television usage. Prospects for development of radiation resistance and wider applications are excellent.

NARF-57-19T(Vol. 4)-8 X-21783

Fries R C
EVALUATION OF RADIATION DAMAGE TO COMMERCIAL ELECTRIC MOTORS,
General Electric Co., ANPO, Cincinnati, Ohio. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 9 pp. (2 refs).

This report summarizes the results of the accelerated aging test of 30 identical commercial electric motors (GE - Model 5KH13DG1A) conducted in the Convair Nuclear Aircraft Research Facility (NARF), Fort Worth, Texas. Alkanex, a promising commercially available radiation resistant magnet wire insulation, and MIL-7808B, a promising sleeve-bearing lubricant, were tested at average temperatures of 356°, 392°, and 428°F. A description of the experiment, reactor test, and test results versus reactor radiation is presented.

A comparison of time-temperature control data with the data from the reactor test indicated that electric motors insulated with Alkanex and MIL-7808B lubricant are adequate for use to temperatures of 430°F for periods up to 700 hours, and dosages of 7.9×10^{14} total neutrons per square centimeters, and 1.5×10^{7} R of gammas.

NARF-57-19T(Vol.4)-9 X-21783

Baxter W G, et al.
HYDRAULIC REGULATOR FUEL CONTROL SYSTEM-GEAR BOX AND ACCESSORY,
General Electric Co., Cincinnati, Ohio. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, Convair, Fort Worth, Texas, May 22-23, 1957, 37 pp. (1 ref).

This report describes the operation of the J47-25 fuel control system, J47-25 gear case, and supporting lubrication tested in the Convair GTR Facility as part of the Systems Panel Test No. 2. Reactor test data and interpretation, post-test operation and examination, and over-all interpretation of test results are included with recommendations for additional engineering-type tests of this general nature.

Systems of the J47 type have had thousands of flight hours in B47 and B36 aircraft. The J79 gear case similar to the one used in this system has passed Official Flight Rating requirements and is now in production.

NARF-57-52T MR-N-173

Miglicco P S, Spears A B and Howell D B
EFFECTS OF REACTOR RADIATION ON THE ELECTRICAL PROPERTIES OF ELECTRONIC COMPONENTS - PART II,
Engineering Department, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, November 22, 1957, 117 pp. (5 refs).

Several types of vacuum tubes, transistors, and transformers were irradiated with the Convair-Fort Worth Ground Test Reactor. The components were subjected to five

different fluxes ranging from 10^6 to 10^{10} nF/cm^2-sec and 10^8 to $10^{12}\gamma$/cm^2-sec. The total integrated flux received was 10^{14} nF/cm^2 and $10^{16}\gamma$/cm^2.

An attempt was made to separate radiation damage as a function of dose rate from radiation damage as a function of dose. The components were irradiated first at several low dose rates so that dose-rate effects could be studied while the accumulated dose was small, and then at a high dose rate to obtain the desired dose. However, because of the long time required to complete a data gathering cycle, the accumulated dose hindered the separation of dose rate and dose effects. Thus, in the report, the damage to the components is reported as a function of integrated flux. For reference, the integrated flux accumulated at each power level is given.

The transformers exhibited the greatest resistance to irradiation. Every important parameter of the transistors deteriorated in the radiation field. Postirradiation tests at room temperature showed no significant recovery in the transistor characteristics. The plate current of 65% of the tubes tested increased during irradiation. This effect, based on postirradiation tests, is considered permanent.

NARF-58-IT(ADD 1) FZK-9-126-1

RESULTS OF SYSTEM PANELS TEST NUMBER 2 - ADDENDUM 1,
Engineering Department, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, January 6, 1958, 157 pp. (refs).

In System Panels Test No. 2 (SPT No. 2), performed at Convair-Fort Worth during late 1956 and early 1957, existing aircraft systems and components were mounted on test panels and irradiated. The Ground Test Reactor (GTR) was used as a radiation source. During the 531.25 hours of actual irradiation, the reactor attained an integrated power of 135 Mwh. Irradiation took place between November 24 and December 19, 1956.

The reactor was operated in a moderator holding tank located in a dry pool. The test panels were deployed around the reactor inside the pool. To determine changes in physical properties and operating characteristics of the test specimens, measurements were made before, during, and after the irradiation period. Pre- and post-irradiation data were accumulated during time intervals of varying length before and after irradiation.

In this addendum, the results of irradiating five test panels supplied by Pratt and Whitney are presented. The panels contained:

1. A J-57 engine
2. A hydraulic pump loop
3. Various types of transducers and electronic control components
4. An alkylbenzene pump loop
5. Fuel control units, power supplies, and amplifiers

The results of the tests on test panel No. 3, referred to as the "Instrumentation" test panel, is reported in two parts. One, covering the transducers, appears in the body of the report, and the other, covering the electronic control components, appears as an appendix. The report on the fifth panel, which held the fuel control units, power supplies, and amplifiers, also appears as an appendix.

NARF-58-1T(ADD 2) FZK-9-126-2

RESULTS OF SYSTEM PANELS TEST NUMBER 2 - ADDENDUM 2,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, January 6, 1958, 143 pp.

In System Panels Test No. 2 (SPT No. 2), existing aircraft systems and components were mounted on test panels and irradiated. The Ground Test Reactor (GTR) was used as a radiation source. During the 531.25 hours of actual irradiation, the reactor attained an integrated power of 135 Mwh.

The reactor was operated in a moderator holding tank located in a dry pool. The test panels were deployed around the reactor inside the pool. To determine changes in physical properties and operating characteristics of the test specimens, measurements were made before, during, and after the irradiation period. Pre- and post-irradiation data were accumulated during time intervals of varying length before and after irradiation.

NARF-58-6T MR-N-185

McMillan W D and Howell D
THE EFFECTS OF REACTOR RADIATION ON THE ELECTRICAL PROPERTIES OF ELECTRONIC COMPONENTS. PART IV - CAPACITORS AND MAGNETIC CORES,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, January 23, 1958, 61 pp. (5 refs).

Several types of capacitors and one type of magnetic core were irradiated by the Convair-Fort Worth Ground Test Reactor for a period of 80 hours. Measurements were made on the components before, during, and after the irradiation.

During exposure to fast neutron and gamma fluxes of approximately 2×10^8 n/cm^2-sec and 4×10^{10} gammas/cm^2-sec, respectively, the capacitors displayed diverse changes in their electrical characteristics. Capacitance changes ranged from a 10% decrease for the tantalum electrolytic capacitors to virtually no change for the ceramic disc and mica capacitors. Insulation resistances of all except the electrolytic capacitors were characterized by prompt decreases from preirradiation values by factors of from 10 to 100. Comparatively small increases in resistance were noted for the electrolytic capacitors.

The magnetic cores were subjected to two separate fluxes. The low-level irradiation was at a level of approximately 2×10^7 fast n/cm^2-sec and 2×10^{10} gammas/cm^2-sec. For the high-level irradiation, the cores were subjected to fast neutron and gamma fluxes of approximately 2×10^8 n/cm^2-sec and 5×10^{10} gammas/cm^2-sec. The cores appeared to be resistant to radiation at these flux levels.

NARF-58-35T MR-N-216

Spears A B
EFFECT OF RADIATION ON THE ELECTRICAL PROPERTIES OF ELECTRONIC COMPONENTS V,
Convair, Division of General Dynamics Corp., Fort Worth, Texas, Contract No. AF33(600)-32054, August 22, 1958, 83 pp.

Nine types of relays were irradiated in the field of the Ground Test Reactor at a constant power level for a period of 92 hours. The integrated fluxes were approximately $10^{12} n_f/cm^2$ and 10^{10} ergs/gm carbon of gamma rays.

The important operational characteristics of the relays were tested before, during, and after the irradiation.

None of the relays suffered effects which would interfere with the functions for which they were designed; however, significant changes occurred which could not be attributed to any observed nonnuclear influences. It is probable, then, that the components were affected by the radiation.

NAVORD-4621 AD-143467

Wieder H H
PERFORMANCE OF SOLID-STATE MATERIALS AND DEVICES SUBJECT TO A NUCLEAR RADIATION FLUX,
US Naval Ordnance Laboratory, Corona, Calif., August 6, 1957, 30 pp. (58 refs).

Solid-state materials and components have been evaluated with respect to changes in their electrical characteristics brought about by a nuclear radiation flux. The effects of nuclear radiation are strongest when the physical properties of the solid depend upon large scale order in the crystalline lattice or when the type, quantity, and arrangement of impurities within the solid are of prime importance.

Calculations indicate that the radiation flux to be expected from a reactor used for powering a large missile or airplane would be of the order of, and probably less than, 10^{11} n/cm^2. Most solid-state devices and materials perform satisfactorily at this dosage.

In general, metals, dielectrics, piezoelectrics, and ferroelectrics show only small radiation damage for dosages below 10^{15} n/cm^2. Semiconductors, however, are affected strongly by neutron- and γ-flux fields. Silicon withstands radiation up to 10^{16} n/cm^2; germanium shows no radiation damage to 10^{12} n/cm^2. Ionic-type semiconductors have a radiation sensitivity intermediate between germanium and silicon. Tests on solid-state components verify the measurements made on constituent materials. Little effect is noted upon capacitors, resistors, inductors, and vacuum tubes for flux values below 10^{15} n/cm^2.

In cases of semiconductor diodes and transistors, additional effects such as photo emfs, photoconductivity, and noise must be considered. Some of these are transient and last only for the duration of the irradiation. Permanent radiation damage occurs at approximately the same dosage level as that indicated above for semiconductor material.

NAVORD-6127

Sery R A and Gordon D I
NUCLEAR IRRADIATION EFFECTS ON FERROMAGNETIC CORE MATERIALS,
Naval Ordnance Laboratory, White Oak, Maryland, June 3, 1958, 72 pp.

Effects of nuclear irradiation on the magnetic properties of 14 representative core materials were investigated. Measurements before, during, and after irradiation were made at a flux level of about 10^{12} n/cm^2 sec for a total integrated neutron flux of $\sim 10^{18}$ nvt.

NAVR-SYM-ACR-2(1)

Burton Milton
BASIC CONCEPTS OF RADIATION CHEMISTRY APPLICABLE TO EFFECTS OF RADIATION ON DIELECTRICS,
University of Notre Dame, Notre Dame, Ind. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 12 pp. (8 refs).

The elementary effects of various radiations are reviewed, and it is shown that they may be divided roughly into Wigner effects (e.g., discomposition) and charged particle effects. The terms M/N and G are defined and their applicability described. The phenomena in an ionization track include ionization and excitation, for the most part localized in spurs separated from each other by an amount determined by the velocity of the incident particle. The initial discussion related both to ionic and extended molecule dielectrics. The following details pertain principally to the latter; i.e., polymers.

Condensed organic systems show only mild indications of nonspecificity under the effects of radiation. Aromatic groups are far less sensitive to radiation than are aliphatic groups and can protect the latter by a process of energy transfer either between or within molecules; for the latter even at a considerable distance. A cage effect in condensed systems tends to reduce the probability of bond rupture as compared with rearrangement processes. These phenomena are shown to be consistent with many of the results obtained on exposure of polymers to high energy radiation.

NAVR-SYM-ACR-2(7)

Levy P W and Dienes G J
RESEARCH ON RADIATION EFFECTS IN INSULATING MATERIALS AT BROOKHAVEN NATIONAL LABORATORY,
Brookhaven National Laboratory, Upton, N.Y. Paper presented at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 12 pp. (6 refs).

Research work in progress at Brookhaven National Laboratory on radiation effects in insulating materials is described. This work is concentrated on high melting inorganic oxides, compounds of mixed ionic and covalent bonding, and organic high polymers. In the organic oxides the formation and nature of color centers induced by gamma and reactor irradiation have been studied. It has been found in α - Al_2O_3 that the coloration due to gamma rays is slight and reaches its maximum value at 3×10^4 r. More significantly, bands specific to reactor irradiation have been found (at 2040 and 2600A) and their growth studied. In most of the crystalline and fused quartz samples studied, broad and complex absorption spectra were found. Corning "purified" fused silica, however, behaves rather similarly to Al_2O_3--gamma sensitivity is very low, but reactor irradiation produces a broad absorption band at $\approx$ 218 mμ with little absorption from 0.3 to 1.0 mμ. In Linde synthetic "spinel" ($MgO \cdot 3 \cdot 5Al_2O_3$) a rather complex absorption spectrum is produced by gamma irradiation. The most interesting feature is the production of stable absorption in the 3000-4000A region with the growth of the absorption approximately linear with exposure in the 10^4 to 10^6 r region. This crystal may be of use as a dosimeter for large doses. Sodium azide, an example of a compound containing both covalent and ionic bonds, is colored by gamma-ray and reactor radiations. The reflection spectra are different for gamma and fast neutron irradiations and are quite sensitive to subsequent heat treatment. The color centers are probably related to the decomposition

of this crystal. In particular, a band appears at 3600A, probably due to color centers, and one at 6000A which might be due to colloidal sodium. Work on high polymers has been focused on gamma-ray induced polymerization of materials in the solid state. Kinetic data have been obtained for the polymerization of crystalline acrylamide to a high molecular weight material. This polymerization can be attributed to a mechanism involving free radicals.

NAVR-SYM-ACR-2(9)

Carter R L
STUDIES OF THE EFFECTS OF RADIATION ON DIELECTRIC MATERIALS,
North American Aviation, Inc., Downey, Calif. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 6 pp. (6 refs).

The high polymer condensed systems on the one hand, and the monatomic crystal diamond on the other hand, tread very closely to the subject of graphite. A major portion of the work carried on for the past several years in the Downey laboratory has actually been directed toward the understanding of other classes of materials: in particular, simple metals and graphite.

The work reported is that of D. R. Westervelt in the field of radiation-induced optical and hardness effects in ionic crystals,[1] A. W. Smith in measurements of low temperature thermal conductivity,[2] and E. L. Colichman and others in the field of radiation stability of higher polymers[3].

No results of interest have yet been obtained in a study of the possibility of improving structural and electrical properties of radomes and airplane canopies by irradiation.

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[1]D. R. Westervelt, "Theory of the Reaction between Alkali Metals and Alkali Halides with Application to the System K-KCL," North Am. Avia. Rept. NAA-SR-1050 (December 15, 1954); "R', Colloidal, and Z-Bands in KCL," Phys. Rev. 94:1438 (1954); "Mechanical Effects of Ionizing Radiation in the Alkali Halides," North Am. Avia. Rept. NAA-SR-888 (May 1, 1951).

[2]A. W. Smith, private communciation.

[3]E. L. Colichman, R. F. Fish, and R. H. Gercke, " Radiation and Thermal Stability of Ortho-Meta, and Para-Terphenyls," North Am. Avia. Rept. NAA-SR-1214; North Am. Avia. Rept. NAA-SR-1026, Progress Report, Chem. Group, January-March (1954); North Am. Avia. Rept. NAA-SR-1087, Progress Report, Chem. Group, April-June 1954.

NAVR-SYM-ACR-2(11)

Primak W
AN ACCOUNT OF SOME INVESTIGATIONS OF RADIATION DAMAGE PRODUCED BY ENERGETIC PILE NEUTRONS IN SOME VALENCE AND IONIC CRYSTALS,
Argonne National Laboratory, Lemont, Ill. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 2 pp. (5 refs).

The investigation of phenomena described by Burton as "discomposition" of graphite was extended to other substances in order to learn how general a phenomenon it was. The

group of substances chosen for investigation was determined by (a) the possibility of showing phenomena similar to that found in graphite, (b) the possibility of investigating them by techniques which had already been developed, (c) the probable stability toward radiations other than energetic neutrons present in the reactor, and (d) the possession of a low cross section for radio-activity induced by pile radiations. Among the substances examined have been diamond, silicon carbide, silicon, germanium, quartz, tridymite, cristobalite, germanium dioxide, magnesium oxide, corundum, spinel, beryl, chrysoberyl, phenacite, and calcium fluoride, representing a variety of compositions and crystal structures ranging through the ionic crystals, valence crystals, and semimetals. The general technique was to expose the samples in various reactor facilities which were available and then measure changes in properties. The most generally useful method of examining the substances for gross disorder is to examine their X-ray diffraction patterns. Other properties whose investigation has proven valuable in particular cases have been heat content, density, specific heat, and optical properties. The detailed behavior of each substance seems to be unique and is a structural matter. However, the general character of the behavior of the irradiated substances proved to be not a new class of phenomena but rather phenomena known for a long time in the case of the metamict minerals, disordered by the alpha particles arising from their natural radioactive content. Large changes in properties were found not only in crystalline substances exposed to pile radiations but also in a glass, vitreous silica; hence, the local order present in a glass is subject to alteration.

No conclusions or data are presented in this paper as it is merely an account of the types of investigations undertaken by Dr. Primak.

NAVR-SYM-ACR-2(12)

Billington D S and Crawford J H, Jr.
THE EFFECTS OF NEUTRON IRRADIATION ON DIELECTRIC MATERIALS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 9 pp. (7 refs).

The effects of irradiation, particularly neutron irradiation, on the properties of materials is of utmost importance to a reactor development program, since such effects may determine the success or failure of a particular reactor design. In addition to structural materials, it is important that effects in the materials that make up auxiliary systems which are important to the operation of a reactor be considered. These are electronic components, vacuum tubes, transistors, capacitors, etc. Moreover, the effects of irradiation on insulating and mechanical properties of plastics and elastomers require consideration, as well as those effects which are produced in various liquids such as lubricants, hydraulic fluids, etc. The Solid State Division of the Oak Ridge National Laboratory has a broad program of study that involves neutron irradiation effects in a wide variety of solids; for example: metals and alloys, semiconductors, plastics, elastomers, ionic crystals, and covalent crystals, in addition to studies in reactor technology.

This paper covers briefly the activities in these fields as carried on at Oak Ridge by the Solid State Division. Included is a summary of advantages and disadvantages of reactors and particle accelerators as research tools.

NAVR-SYM-ACR-2(18)

Pomeroy G W
DETERMINATION OF THE EFFECTS OF RADIATION FIELDS ON DIELECTRIC MATERIALS,
General Electric Company, Cincinnati, Ohio. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 6 pp. (1 ref).

Almost all materials will undergo some change in physical and chemical properties when exposed to radiation fields. This phenomenon established the need for studies to determine the effects of radiation fields on dielectric materials used in electrical and electronic equipment from nuclear power plants. This paper is written to describe experimental procedures for determining and measuring these effects and to present typical experimental data.

Many types of radiation fields and sources have been used in the radiation damage programs including the Oak Ridge National Laboratory's graphite pile, the Low Intensity Training Reactor, the Materials Testing Reactor, Van de Graaff accelerators, and cobalt-60 gamma sources. The dielectric materials tested include a large number of organic liquids, lubricants, plastics, elastomers, and ceramics.

NAVR-SYM-ACR-2(21)

Mannal C
RADIATION EFFECTS ON DIELECTRIC MATERIALS,
Knolls Atomic Power Laboratory, Schenectady, N.Y. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 15 pp.

For the most part, work on dielectrics and dielectric structures at the Knolls Atomic Power Laboratory has been guided by the necessities of the submarine reactor program now under way at this Laboratory.

The coolant of the Submarine Intermediate Reactors, now under construction both at West Milton, N.Y. and at General Dynamics Corporation, Groton, Conn., is liquid sodium. This material, on passage through a reactor, becomes intensely radioactive and emits gamma rays of 1.38 and 2.76 Mev. Their half-life is 15 hours. The linear induction pump used for transporting the sodium around the coolant loop consists essentially of a flat, wide duct with a magnetic structure above and below to supply the traveling wave which gives motion to the sodium. Proximity of the magnetic structure to the hot, radioactive sodium requires insulation which is highly reliable, is capable of operation at temperatures in the vicinity of 200°C, and which will withstand radiation fields of hundreds of thousands of r/hr. A life expectancy of many years is desired.

Inorganic materials appeared greatly superior to organic materials at the time the selection of insulating materials for this pump had to be made. Therefore, a bar insulation of glass yarn, mica tape backed with glass cloth and impregnated silicone resin was chosen. Much of the last two years have been spent in an investigation of this structure. It is concluded that it is a highly satisfactory insulation system for the intended purpose.

This paper covers the tests applied to the materials and subsequent improvements. Further information is contained on the radiation resistance of optical glasses as used in special periscopes used for viewing areas of intense radiation in the SIR reactor.

NBS-5335

Van Ness H N and French J C
EXPLORATORY MEASUREMENTS OF THE EFFECTS OF GAMMA RADIATION ON SMALL SIGNAL PARAMETERS AND I_{CBO} PF TYPE 2N43A TRANSISTORS,
National Bureau of Standards, Washington, D.C., June 18, 1957, 33 pp.

The study given below represents a portion of the program carried out in the Radiation Physics Laboratory for the Department of Defense. The general purpose of this program is to evaluate radiac instruments with particular regard to their response over a wide range of dose rates and spectral energies of the incident radiation, and their stability when operated for extended periods of time under various environmental conditions. Many of the instruments are in the developmental stage, and it is expected that design factors will be evaluated. The present report is concerned with studies of Type 2N43A transistors to determine their suitability as components of radiac equipment. The specific tests consisted of measurements of the effect of gamma radiation on small signal parameters of these transistors. The study was carried out with the assistance of the Bureau's Electricity and Electronics Division. The samples of the 2N43A transistors were submitted for this study by the Bureau of Ships Code 854.

NRL-5161

Salkovitz E I, Bailey G C and Schindler A I
EFFECT OF NEUTRON IRRADIATION ON THE CURIE TEMPERATURE OF A VARIETY OF FERRITES,
Naval Research Laboratory, Washington, D. C., July 1, 1958, 5 pp.

A variety of commercially available ferrites were irradiated in the Brookhaven reactor for a total integrated flux of 1.2×10^{17} nvt (fast), at a temperature of 50°C. None of the samples showed a significant change in the Curie temperature.

NRL-MR-146

McClinton A T, et al.
ENGINEERING PHYSICS OF DIELECTRICS--PROGRESS REPORT NO. 1,
Shipboard Systems Branch, Electricity Division, Naval Research Laboratory, Washington 25, D.C., April 1, 1953, 43 pp. (5 refs).

This progress report covers three areas of activity: radiation effects on dielectrics, functional evaluation of insulating systems, and nondestructive testing of insulation.

Dielectric tests have been run using a 2.5-curie source of Co^{60}. Teflon, Formex, and Fiberglass have been tested with no discernible changes in capacitance and dissipation (hence, AC resistance) at 1000 cycles. Reductions in DC resistance at 100 volts have been noted.

Additional studies are planned as soon as a 2000-curie source and 2 Mev Van de Graff accelerator can be procured.

NRL-MR-218

McClinton A T, et al.
ENGINEERING PHYSICS OF DIELECTRICS--PROGRESS REPORT NO. 2,
Shipboard Systems Branch, Electricity Division, Naval Research Laboratory, Washington 25, D.C., October 1, 1953, 24 pp. (11 refs).

The past six months have brought all phases of this program into the experimental stage. Radiation sources have been received and installed for the study of radiation effects on dielectrics. These sources include 2500 curies of Co^{60} and a 2-Mev Van de Graaff electron accelerator. A program of study centered around these is now in progress. The basic instrumentation is nearly complete permitting the direction of many activities of this project towards the obtainment of applicable engineering data. With the accumulation of experimental information, it is intended to develop additional instrumentation to measure mechanical and chemical changes. Concurrently, a theoretical approach will be crystallized to determine more accurately the causes of property changes resulting from radiation.

Preliminary studies with models of motors (motorettes) have been completed, and the functional evaluation of insulation systems has been formally started.

NS-0858-1

Davidson R A and Rosen B H
EFFECTS OF RADIATION ON VIDICON PERFORMANCE,
IRE Transaction on Nuclear Science, Vol. 5, No. 2, pp. 46-49, August (1958).

A commercial 1-inch vidicon was exposed to a total radiation dosage of approximately 10^{15} nvt in the Brookhaven National Laboratories Nuclear Pile Reactor. Quantitative tests were devised for measuring tube aperture response, signal, noise, and photoconductor "dark" current.

No measurable degradation of performance occurred, except for decrease in signal output, which was attributed to radiation browning of vidicon glass faceplate.

ORNL-57-12-125

Pigg J C
THIRD QUARTERLY LETTER PROGRESS REPORT,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. AF33(616)-57-17,
December 23, 1957.

This report contains two articles. The first, entitled "Irradiation Effects in Photo Cells," directs its attention toward the effects of neutron and gamma radiation on chemically deposited, thin films of lead sulfide. The second, entitled "Irradiation Effects in Semiconductor Barriers," presents a survey of pertinent work in this area at ORNL, along with a summary of the basic concepts upon which this work is based. Both semiconductor materials and semiconductor devices are discussed.

ORNL-277

Stilson C E
THE EFFECT OF RADIATION ON A DIFFERENTIAL TRANSFORMER,
Oak Ridge National Laboratory, Oak Ridge, Tenn., August 16, 1948, 12 pp.

This report describes the testing of a differential transformer in an operating pile to determine the suitability of the differential transformer as a position-sensory instrument in determining the elongation of a test bar in creep test radiation damage studies.

ORNL-1540

Sturn W J and Jones R J
APPLICATION OF THERMOCOUPLES TO TARGET TEMPERATURE MEASUREMENTS IN THE INTERNAL BEAM OF A CYCLOTRON,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, November 17, 1953.

Results obtained with lead (m. P. 960.5C) are shown. In each case, the measured melting point was within ±3.7°C of the melting point, and the accuracy of the measurement was well within potentiometer circuits used in this typical application.

ORNL-1700

Weeks R A and Binder D
EFFECTS OF RADIATION ON THE DIELECTRIC CONSTANT AND ATTENUATION OF TWO COAXIAL CABLES,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, March 19, 1954, 13 pp. (8 refs).

Measurements have been made on radiation-induced changes in the phase constant and attenuation of two coaxial cables while being irradiated. The measurements were made in the region of 4 MC. At this frequency the change in dielectric constant was 1.4 ± 0.4 % for both dielectrics after roughly 2×10^{18} nvt. The change in attenuation was 9 ± 2% for polyethylene and within the range of error for teflon. The phase constant and attenuation were found by measuring the input impedance of an open-ended length of cable in the neighborhood of its quarter-wave frequency. Assuming a uniform cable dielectric and no other variables, the input impedance has a minimum at this frequency. From the minimum the attenuation and phase constant are found.

ORNL-1852

Howe J T (Editor)
SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING FEBRUARY 28, 1955,
Solid State Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.,
Contract No. W-7-7405-Eng-26, June 10, 1955, 161 pp. (101 refs).

This report covers work performed at ORNL in the Solid State Division. The subjects investigated are as follows: (1) energy levels in fast-neutron irradiated p-type germanium, (2) effect of bombardment, on hole mobility in p-type germanium, (3) photoconductivity and minority-carrier traps in bombarded n-type germanium, (4) annealing of irradiated germanium, and (5) determination of energy levels in germanium by transmutation doping.

ORNL-1945

Billington D S (Director)
SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING AUGUST 30, 1955, Solid State Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, January 30, 1958, 81 pp. (21 refs).

This report covers the progress of the Solid State Division during the period February 28 through August 30, 1955. Work in each of four areas is outlined below:

Solid State Reactions

Fast-neutron irradiation was found to produce interstitials and vacancies in the semiconducting, intermetallic compound gallium antimonide, and vacuum heat treatments preferentially anneal the interstitials, leaving an excess acceptor concentration. The effects of reactor irradiations on the electrical properties of electrical insulation were found to be accelerated aging plus the generation of semiconductor-like properties in the insulator. Further work was performed on neutron irradiation and magnetic susceptibility of indium antimonide. In additon, magnetic susceptibility studies of germanium, quartz, and TiD_2 were continued with successful results.

Optical spectra properties of irradiated silicone glasses were measured and efforts were made to determine annealing processes.

Engineering Properties

A study is being made of the physical properties of a variety of ceramic materials which have been exposed to reactor irradiation.

Radiation Metallurgy

Metallurgy during the period was confined to pre- and post-irradiation tests of steels in the Homogeneous Reactor Project.

Nuclear Measurements

Flux-depression experiments were conducted at MTR to compare 1/v absorbers to resonance-type absorbers, also miniature fission chambers using Np^{237}, U^{236}, and some other materials.

Flux measurements of the BNL Graphite Reactor were completed. The use of gamma-ray scintillation spectrometer techniques for analysis of beryllium is discussed.

Special Projects

Resistivity changes in alpha brass as a function of neutron irradiation were detected but not correlated. Agreements in results were obtained in both single crystals of brass and polycrystal experiments. The neutron radiation effect on precipitation hardening in nickel-beryllium correlated well with theoretical analysis.

Electron-Spin resonances in irradiated Corning silica glass were measured and analyzed. The annealing kinetics of neutron-irradiated lithium fluoride were derived from data on irradiated crystals. The quenching effects gold-cadmium alloys were investigated. These included measurements of resistivity and density.

X-ray diffraction measurements of irradiated ceramics and glasses were made and studied. Results of these studies are included.

ORNL-2081-52

Simon A
DIFFUSION OF IONS IN A PLASMA ACROSS A MAGNETIC FIELD,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

The diffusion rate of ions across a magnetic field has been investigated both experimentally and theoretically. The resultant diffusion coefficient is found to vary inversely as the square of the magnetic field strength, in accordance with the usual collision-diffusion theory. The magnitude of the coefficient is much larger (x 700) than the coefficient predicted by the usual ambipolar diffusion theory. This discrepancy is resolved by showing that diffusion across a magnetic field is not ambipolar in character in most arc experiments. The final experimental and theoretical values are in good agreement, and it is unnecessary to postulate any additional diffusion mechanixms, such as plasma oscillations.

ORNL-2081-53

Simon A
DIFFUSION OF LIKE PARTICLES ACROSS A MAGNETIC FIELD,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

The diffusion rate across a magnetic field due to collision of like charged particles is derivable from the macroscopic equations of the plasma. However, it is necessary to include the off-diagonal terms in the stress tensor. The resultant diffusion rate does not obey Fick's law and is proportional to the inverse fourth power of magnetic field strength.

PB-131423

ENVIRONMENTAL REQUIREMENTS GUIDE FOR ELECTRONIC PARTS,
Department of Defense, Advisory Group on Electronic Parts, Office of the Assistant Secretary of Defense, Research and Engineering, October (1957), 7 pp.

Electronic parts must be capable of sustained operations not only under the conditions required of the prime equipment to which they are applied, but also in their environments within that equipment. To assist in achieving these objectives, this document establishes a guide for research and development requirements for environmental design, to be used in current and future electronics planning, as well as appropriate test procedures.

Environmental requirements are broken down into 10 categories or groups by use to which the component is to be put. The requirements of each group are outlined in each of the environments listed below:

Temperature
Pressure
Moisture
Vibration
Shock
Air-Induced Vibration
Acceleration
Explosive Atmospheres
Nuclear Radiation
Sand and Dust
Salt Spray
Flammability
Fungus
Life

The methods of testing and measurements for each condition are explained.

PDCPC-3742-MM

Arbuthnott J, Jr. and McKean A L
STYROFLEX CABLE CHARACTERISTICS UNDER NUCLEAR RADIATION,
Phelps-Dodge Copper Products Corporation, Research Laboratories, Yonkers, N.Y.,
April 20, 1959, 6 pp.

The Research Laboratory was requested to study the performance of styroflex cable in strong nuclear radiation fields such as those where control cables must run to monitor radiation intensity in nuclear reactors. One of the most critical problems associated with this application is one of noise. It was considered most essential to measure the effect of nuclear ionization in the styroflex cable caused by nuclear bombardment with reference to increased noise levels in the cable. This report summarizes the results of electrical measurements made on 3/8, 50-ohm styroflex cable while exposed to strong nuclear fields in the research reactor at Brookhaven National Laboratory.

PR-1057

Bemski G and Augustyniak W M
ANNEALING OF ELECTRON BOMBARDMENT DAMAGE IN SILICONE CRYSTALS,
Phys. Rev., pp. 645-648, October-December (1957).

Silicon crystals were bombarded at room temperature with electrons of 700 kev from a Van de Graaff accelerator. The annealing of the bombardment damage was studied between 200° and 400°C by observing the recovery of the minority-carrier lifetime. The annealing was found to proceed with an activation energy of 1.3 ev. This is interpreted as being the activation energy associated with the lattice jump frequency.

The kinetics of the annealing are identical in most p-type and n-type crystals. A second order process has been identified toward the end of the annealing. Evidence is given that crystalline defects can influence the annealing kinetics.

PUR-NP-7109

Longo Thomas Anthony
NUCLEAR IRRADIATION OF SILICON SEMICONDUCTORS,
Department of Physics, Purdue Univ., Purdue, Ind., August (1957), 180 pp. (36 refs).

There is a great interest in the effects of high energy nucleon irradiation on matter. In particular, the physical properties of semiconductors have been found to be very sensitive to the disorder introduced by energetic nucleon irradiation. However, most of the previous information had been obtained for germanium. Therefore, the object of this work was to investigate the effects of nucleon irradiation on the electrical and optical properties of silicon.

After fast-neutron irradiation, the inverse temperature dependence of the logarithms of Hall coefficient and resistivity of both n-type and p-type single crystal silicon samples indicated that intrinsic behavior was approached in each sample. A 1.75μ peak in the optical absorption coefficient was observed. This peak is believed to result from optical excitation rather than ionization of an introduced defect level, since it is not accompanied

by an increase in photoconductivity. Appreciable photoconductivity was observed beyond the fundamental region to about 1.45 microns.

Annealing experiments were continued on a polycrystalline p-type silicon sample which had been previously irradiated with fast neutrons. After annealing at temperatures ranging from 150^{o} to 250^{o}C, the slopes of the logarithms of Hall coefficient and resistivity vs $10^{3}/T$ decreased, suggesting the rearrangement of introduced defect levels accompanying annealing. During annealing, the absorption peak at 1.75μ gradually disappeared and an absorption tail extending past 30μ increased.

Quantitative information was needed in order to establish the nature and numbers of the defects introduced by the irradiation. Therefore, n- and p-type silicon were irradiated with 9.6 Mev deuterons from the Purdue cyclotron. The Hall coefficient and conductivity of degenerate and nondegenerate samples were measured as a function of irradiation. The carrier concentrations of all samples were reduced by irradiation.

For n-type degenerate samples, the change in carrier concentration with flux $\Delta n/\phi = -67$ electrons cm^{-1} per deuteron, and for p-type degenerate samples $\Delta p/\phi = -750$ holes cm^{-1} per deuteron. These compare favorably with a calculated rate of defect pair introduction $\Delta N/\Delta\phi = 775$ defect pairs cm^{-1} per deuteron, with one carrier removed per pair.

This work supports the belief that the introduction of close vacancy interstitial pairs is the predominant effect of irradiation.

The changes of carrier concentration with flux decreased rapidly as the Fermi level moved into the forbidden band. The interstitial states appeared to be at 0.025 ev from conduction band and the vacancy states at 0.055 ev from the valence band.

For heavy irradiations, the removal rates were lower in the degenerate and higher in the nondegenerate regions than what was observed for smaller irradiations. This suggested clustering of defects and the states associated with these clusters appeared to be introduced deep in the forbidden gap.

REIC-1 AD-147399

Reid F J, Moody J W and Willardson R K
THE EFFECT OF NUCLEAR RADIATION ON SEMICONDUCTOR MATERIALS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
Contract No. AF33(616)-5171, December 20, 1957, 32 pp. (44 refs).

This report is a survey of the present state of the art of radiation effects in semiconductor materials. This work is primarily of a fundamental nature. The experiments described were designed to reveal basic types of damage. In some cases, it will be noted that very large fluxes (up to about 10^{19} nvt in case of neutrons) were used in these experiments to produce significant changes. With proper understanding of the mechanisms involved in radiation damage, as obtained from these experiments, useful predictions concerning the damage of many materials will be possible.

At present, it appears that germanium is relatively radiation resistant. For germanium which is presently being used for devices (1 to 30 ohm-cm), the minority-carrier lifetime and the conductivity begin to be affected around 10^{11} fast neutrons per cm^{2}. If less pure germanium is used (<1 ohm-cm), it becomes more radiation resistant. Since germanium devices are unable to operate at temperatures much in excess of 100^{o}C, they are

being replaced by silicon in military applications where high ambient temperatures are involved. On the other hand, silicon appears to be much less radiation resistant than germanium, by as much as a factor of 2. There is a significant lack of information about irradiation damage in silicon.

With the information obtained thus far, it appears that the development of compound semiconductor materials suitable for devices is the next logical step. These materials should have high mobilities and would have to possess a large energy gap (1.1 to 2 ev) to permit operation at elevated temperatures. They should consist of atoms which are at least as massive as germanium atoms to be radiation resistant. It would be desirable to develop a material such that when operated at temperatures between 200° and 500°C, the rate of annealing is comparable to the rate of radiation damage for practical equilibrium defect concentrations and levels of irradiation.

To have a complete picture of the mechanisms involved in annealing, more irradiation should be performed at very low temperatures (at and below 80°K). This is particularly true in the case of compound semiconductors where annealing studies may help to differentiate between the various types of defects.

REIC-1(Add 1) AD-210758

Aukerman L W
THE EFFECT OF NUCLEAR RADIATION ON SEMICONDUCTOR MATERIALS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
March 31, 1959, 30 pp. (116 refs).

The literature on the effects of high-energy-radiation semiconductor materials received by the REIC during 1958 and 1959 has been reviewed and compared. The materials covered are germanium, silicon, and several compound semiconductors including indium antimonide, gallium antimonide, indium arsenide, aluminum antimonide, and gallium arsenide. All types of irradiation capable of producing permanent damage are considered. A rather serious discrepancy between theory and experiment appears to be present in most cases investigated.

REIC-2 AD-149551

Hansen J F, Harrison S E and Hood W L
THE EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS AND SYSTEMS,
REIC, Battelle Memorial Institute, Columbus 1, Ohio, Contract No. AF33(616)-5171,
December 31, 1957, 20 pp.

This report presents the state of the art of the effect of nuclear radiation on electronic components and systems from 1947 to the present. A brief history of radiation effects work is followed by a tabular presentation summarizing radiation effects information on electron tubes, capacitors, resistors, semiconductors, magnetic core material, transformers, batteries, printed-circuit boards, thermocouples, tapes, and strain gages.

REIC-TM-4

Aukerman L W and Reid F J
ENERGY LEVELS PRODUCED IN SEMICONDUCTORS BY HIGH-ENERGY RADIATION,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
Contract No. AF33(616)-5171, July 15, 1958, 30 pp. (47 refs).

The objectives of this report are to review and compare the methods employed by various investigators for determining bombardment-produced energy levels in semiconductors and to compare their results. The greater portion of the report is concerned with the methods for determining the energy levels.

There are four of these methods which are: (1) carrier concentration versus flux; (2) temperature dependence of carrier concentration; (3) minority carrier lifetime measurements; and (4) photoconductivity and optical absorption.

REIC-TM-5

Hassler K E, Hansen J F and Wyler E N
THE EFFECT OF NUCLEAR RADIATION ON TRANSISTORS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
Contract No. AF33(616)-5171, November 30, 1958, 13 pp. (14 refs).

The designer, in selecting a transistor type for a specific application, must consider the radiation-induced transient effects that are manifested as increased leakage currents and induced voltages, semipermanent effects which disappear after removal of the radiation, and the permanent effects that increase as a function of continued exposure. Silicon transistors are generally more susceptible to radiation damage than are germanium units; thick-base transistors are more susceptible than thin base. Both the method of encasement and the contents used to backfill the case influence radiation damage susceptibility.

REIC-TM-6

Drennan J E and Harrison S E
THE EFFECT OF NUCLEAR RADIATION ON SEMICONDUCTOR DIODES,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
Contract No. AF33(616)-5171, December 31, 1958, 16 pp. (32 refs).

This memorandum discusses the effect of nuclear radiation on semiconductor diodes. Several illustrations show the effect of radiation on the forward and reverse characteristics of a number of diodes. Semiconductor diode behavior under nuclear radiation is summarized. Both silicon and germanium type diodes are discussed.

REIC-TM-7

Hansen J F
EFFECT OF NUCLEAR RADIATION ON ELECTRONIC TRANSFORMERS AND TRANSFORMER MATERIALS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
Contract No. AF33(616)-5171, November 30, 1958, 4 pp. (5 refs).

This memorandum presents a summary of the information available in the REIC files on the effects of nuclear radiation on transformers and transformer materials. Recommendations regarding materials for transformer construction are also presented. The materials discussed are: transformer iron; and transformer insulations, windings, impregnations, structures, terminals, and fittings.

REIC-TM-12

Reid F J and Moody J W
THE EFFECT OF NUCLEAR RADIATION ON MAGNETIC MATERIALS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
December 31, 1958, 14 pp. (28 refs).

This memorandum discusses the effect of nuclear radiation on soft and hard magnetic materials. Information is given showing the change in permeability, coercive force and remanence as a function of radiation levels. A list is included which gives the organizations presently doing work on radiation effects in magnetic materials.

REIC-TM-14

Moody J W
THE EFFECT OF NUCLEAR RADIATION ON ELECTRICAL INSULATING MATERIALS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
March 31, 1959, 10 pp. (11 refs).

The failure of electrical insulation in nuclear-radiation environments is primarily due to the mechanical and physical deterioration of the materials rather than to gross changes in their dielectric properties. The ionizing effects of radiation in organic insulators lead to a series of complex chemical reactions (predominantly cross-linkage or chain cleavage) which drastically alter the nature of the material. The integrated fast-neutron breakdown flux for the most radiation stable of the organic insulators, polystyrene and polyethylene, is estimated to be 10^{20} and 10^{19} n/cm^{-2}, respectively. Elevated temperature, a common adjunct of a nuclear-radiation environment, tends to advance the deterioration of organic materials.

Except for glass, the inorganic materials used as insulators are much more radiation resistant than are the organic polymers. Damage in ceramic substances arises from atomic displacements and is manifested as changes in the lattice parameters, strength, electrical properties, and dimensions. Most ceramic materials are able to withstand integrated fast-neutron fluxes of 10^{22} n/cm^{-2} before they become unsatisfactory as insulators. The radiation damage suffered by ceramic insulators may be annealed at elevated temperatures.

Both types of material, organic and inorganic, show strong photoconductive effects when placed in a radiation field. The increased current leakage resulting from this effect may constitute a problem for certain applications of insulators.

REIC-TM-011558

Lamale G E and Schall P
ELECTRICAL LEAKAGE IN INSULATORS EXPOSED TO A NUCLEAR ENVIRONMENT,
REIC, Battelle Memorial Institute, Columbus 1, Ohio, Contract No. AF33(616)-5171,
January 15, 1958, 4pp. (5 refs).

This technical memorandum discusses briefly the history of transient behavior of radiation-induced changes in electrical resistance of insulators. The more recent work is also discussed.

Two tables are included: resistivity of insulators after reaching equilibrium and resistivity as a function of dose for various insulators.

SCTM 90-59(51)

McIver F M
INSTRUMENTATION OF EXPERIMENTS ON N-TYPE GERMANIUM AT THE LOS ALAMOS GODIVA FACILITY,
Sandia Corporation, Albuquerque N. M., Contract No. AT-(29-1)-789, March 24, 1959, 11 pp.

The sample preparation, instrumentation, and control systems for several experiments made on N-type germanium at the Godiva radiation facility are described.

SCTM 181-58(16)

Tschaeche A N
THE PENETRATION OF PRINTED CIRCUIT BOARDS BY ETCHING SOLUTION,
Sandia Corporation, Albuquerque, N. M., Contract No. AT-(29-1)-789, June 12, 1958, 20 pp. (4 refs).

The penetration of etching solution into the unfinished edges of printed circuit boards 1/16-inch thick was studied using radioisotope tracer techniques. It was found that the etchant, in this case ferric chloride, penetrated boards with the following types of insulation to a depth of about 1/8 inch: glass epoxy, glass melamine, paper phenolic, and nylon phenolic. Boards using glass silicone insulation were penetrated to a depth of at least 1/2 inch. Very little, if any, further penetration occurred after the boards were removed from the etchant. The amount of etchant penetrating the first 1/8 inch of the boards varied from 2.50×10^{-6} grams of $FeCl_3$ per inch of exposed edge in the case of glass-epoxy insulation, to 260×10^{-6} grams of $FeCl_3$ per inch of exposed edge in the case of glass-melamine insulation.

SCTM 187-58(51)

Stein H J, Berner R R and McIver F M
THE EFFECTS OF A PULSE OF NEUTRONS AND GAMMAS ON N-TYPE GERMANIUM,
Sandia Corporation, Albuquerque, N. M., Contract No. AT-(29-1)-789, June 19, 1958.

The effects of a pulse of neutrons on the hole lifetime in N-type germanium were investigated and compared with the effects of reactor irradiation on similar material. Information on the minority carrier decay immediately after the neutron pulse was also obtained along with conductivity changes in a 30-minute period after the pulse. No dose rate effects could be established from a peak exposure rate of 10^{19} $n_f vt/sec$ by making before and after (5 days) irradiation measurements of the minority carrier lifetime. A minority carrier lifetime determined from the photoconductivity-decay immediately after the burst is larger by approximately a factor of 8 than a lifetime measured 5 days later. The conductivity decreased during the first 5 minutes after the burst. However, 10 minutes after the burst, the conductivity began to increase again. The temperature change of the sample was $0.5^{o}C$. The conductivity changes therefore suggest that an annealing process must be occurring immediately after the burst.

SCTM 207-58(51)

Berner R R and Stein H J
A PROPOSED THEORY TO EXPLAIN ANNEALING OF RADIATION-INDUCED CHANGES OF CONDUCTIVITY IN GERMANIUM AFTER A SHORT PULSE OF NEUTRONS,
Sandia Corporation, Albuquerque, N. M., Contract No. AT-(29-1)-789, July 23, 1958, 9 p.(5 refs)

Annealing of radiation-induced changes of conductivity in germanium was observed as a function of time after a short pulse of neutrons. The observed changes are explained in a qualitative theory as being due to the recombination of "near" and "far" vacancy-interstitial pairs. A discussion of the validity of the theory and substantiating experiments is presented.

SCTM 210-57(51)

Stein H J
IRRADIATION DAMAGE TO SEMICONDUCTORS,
Sandia Corporation, Albuquerque, N. M., Contract No. AT-(29-1)-789, August 28, 1957, 17 pp. (14 refs).

A survey of literature on the effects of neutron and gamma irradiation of semiconductor materials has been made to determine the present ideas regarding the nature of radiation damage and the effort being applied to the studies throughout the nation.

There is a gap at present between the capability of measuring the bulk properties of irradiated materials and adequately predicting device behavior. Some work at other laboratories is being directed toward closing the gap. It may be valuable to follow experiments and parallel them using high dose rates from Nevada tests and Godiva.

Since Sandia Corporation is in an advantageous position for utilizing high dose rate facilities, we should be capable of making contributions to the existing fund of knowledge on radiation effects to semiconductor materials and devices.

SCTM 385-58(14)

Westmark C I
TRANSIENT BEHAVIOR OF SELECTED SEMICONDUCTOR DEVICES DURING NUCLEAR RADIATION,
Sandia Corporation, Albuquerque, N. M., Contract No. AT-(29-1)-789, January 22, 1959, 39 pp.

This report deals with semiconductor device transients during bursts of neutron and gamma radiation. Radiation-induced permanent damage data are recorded; however, this aspect of the test program is not discussed herein.

TID-5214

Baldock C R and Hudson E D
ELECTRICAL EQUIPMENT FOR TANKS AND MAGNETS,
USAEC, Technical Information Service, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April (1947), 401 pp.

It is the purpose of this report to give an account of the electrical engineering phases of the electromagnetic separation process as they relate particularly to the electrical equipment for the tanks and magnets used in operating the calutron for the separation of isotopes.

In general each topic is treated on five points: (1) equipment as received on the job, (2) changes made in the equipment as received to make it operable, (3) service conditions, (4) service record, and (5) experimental and theoretical studies made.

The main subjects covered include the magnet with supply equipment and controls, the high-voltage supplies for tanks used, and the tank auxiliary electrical equipment. The primary power-distribution system was omitted since it is conventional. In the section on the magnet, details of the magnet and its supply along with two types of current regulators used are presented. A discussion of protective gaps is also included. In the section on the electrical equipment for tanks and magnets, the two high-voltage power supplies associated with the three types of calutrons used in the plant and the auxiliary power supplies that were required for operation of the ion sources are discussed.

UCRL-3084

Voelker Ferdinand and Leavitt Menard A
A MAGNETOMETER FOR MEASURING FIELDS TO 300 GAUSS,
University of California Radiation Laboratory, Berkeley, Calif., Contract No. W-7405-Eng-48, July (1955) 8 pp.

This report describes the development of an instrument for the measurement of a magnetic field in an electron cyclotron which has the following characteristics: (a) accuracy of 0.1% to fields of 100 gauss, (b) continuous monitoring of magnetic field to allow automatic plotting of field versus position of the probe, and (c) quadrupole probe construction, minimizing the effect of nearby iron on the measurements. Two newer versions of the probe have been built, one for measurement of the earth's field which sacrifices field range above 10 gauss for small size, and the other for fields to 300 gauss which sacrifices quadrupole construction.

USASRDL-2007

Long Alton L and Degenhart Hans J
TRANSIENT EFFECTS OF PULSE NUCLEAR RADIATION ON ELECTRONIC PARTS AND MATERIALS,
U.S. Army Signal Research and Development Laboratories, Fort Monmouth, N.J., January 20, 1959, 52 pp. (3 refs).

Transient changes of the electrical characteristics of selected electronic parts (capacitors, resistors, semiconductor diodes, relays and cables) induced by their exposure to the short-time high-peak neutron flux pulse of the Godiva II reactor were recorded dynamically as they occurred, by using a specially developed monitoring system consisting essentially of frequency deviation oscillators and multi-channel high-speed magnetic tape recorders.

The results obtained for these parts show a very wide range of response to the nuclear pulse irradiation. No detectable effects occurred in relays. Coaxial RF cable showed a slight transient decrease in capacitance. Ceramic and glass capacitors increased in capacitance by several times their original value, recovering completely within a few milliseconds. The leakage current of tantalum capacitors behaved in a complex manner recovering within 6 seconds or less. Changes in capacity, however, of this type of capacitor were not measured. One-megohm carbon film resistors increased in resistance by more than 10% (limit of measurable range) requiring recovery time from 1/2 to 10 seconds depending on the integrated neutron flux. Silicon and selenium diodes showed pronounced transient effects with respect to both leakage current and forward voltage drop.

This first experiment has conclusively demonstrated that low dose, high peak intensity nuclear radiation pulses can cause serious malfunctioning of certain electronic parts and materials, and that this behavior is not always related to the effects observed after low intensity radiation exposure of equal or high cumulative dosage.

WADC-TN-55-639 AD-80851

Panos R J
GAMMA IRRADIATION OF GERMANIUM TRANSISTORS,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December (1955), 45 pp.

One-hundred germanium transistors were irradiated by a gamma source, Co^{60}, for various periods of time. This was done to determine the effect of controlled amounts of radiation on these transistors. As the exposed radiation time is increased, a corresponding increase is observed in the change of the four parameters under study from the initial values.

WADC-TN-56-115 AD-104374

Panos R J
GAMMA IRRADIATION OF GERMANIUM AND SILICON TRANSISTORS,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, March (1956), 103 pp. (Refs).

Two-hundred transistors were exposed to a gamma source, Co^{60}, for various periods of time varying from 25 hours to approximately 200 hours. These units were electrically tested before radiation and at the following intervals after radiation: 0, 25, 50, and 100 hours. One-hundred units were germanium and the other one hundred were silicon transistors. Alpha (current gain) decreased as the period of radiation increased for both germanium and silicon transistors. Silicon Type 904A had the least negative slope and silicon Type 905 had the greatest negative slope. With increasing radiation, I_{CO} increased greatly for germanium transistors with increased radiation. The silicon units did not recover as rapidly as the germanium units after radiation. More data and tests must be made in order to conclude which type of transistor, silicon or germanium, is less susceptible to radiation. Also neutron radiation, which has not been covered by this report, must be taken into account in the final analysis.

WADC-TR-57-492 (Vol. 1) AD-155527

Harms Harold B and Fraser James C
ULTRA HIGH TEMPERATURE MINIATURE POWER TRANSFORMERS AND INDUCTOR MATERIALS,
Specialty Transformer Dept., General Electric Co., Contract No. AF33(616)-3623, May (1958).

The development of electronic power transformers capable of operation in a 500°C ambient temperature and in intense nuclear radiation. Steps to accomplish this involved (1) evaluation of the transformer basic materials alone, (2) evaluation of combinations of the basic materials in transformers, and (3) the development of ceramic processes and supporting members to give mechanical and moisture protection to the transformers. Tests were performed under combined high temperature and radiation conditions. Mechanical tests were also combined with high temperatures.

WADC-TR-57-492 (Vol. 2) AD-155528

Harms Harold S and Fraser James C
ULTRA HIGH TEMPERATURE MINIATURE POWER TRANSFORMERS AND INDUCTOR MATERIALS,
Specialty Transformer Dept., General Electric Co., Contract No. AF33(616)-3623, May (1958).

Three tests were carried out at the Brookhaven National Laboratory under environmental conditions of high temperature and nuclear radiation.

Component tests show that transformers can be built to operate satisfactorily for 1000 hours under the required radiation and temperature conditions. These tests indicate that the greater effect, by far, on material properties and transformers operating values is that of high temperature.

WADC-TR-58-21 AD-142293

Osborn J A, et al.
SOLID STATE RESEARCH FOR THE ADVANCEMENT OF ELECTRONIC MATERIALS,
Aeronautical Research Laboratory, Westinghouse Electric Corp., East Pittsburgh, Pa., Contract No. AF33(616)-304, January (1958), 16 pp. (7 refs).

The final summary report includes: the results of measurements of the magnetostriction and anisotropy constants of 31 different single crystal alloys, the status of the Magnetic Materials Handbook, the high temperature measurements of the nickel-iron alloys, and the effects of composition and processing variables on the magnetic properties of 50-50 nickel iron.

The crystals whose data are reported are those to be subsequently irradiated; following this treatment, changes in their magnetic and structural properties will be studied. Besides the 7 aluminum-iron alloy compositions previously reported, crystals of 6 nickel-iron, 5 silicon-iron, 3 cobalt-nickel, 3 cobalt-iron, 2 molybdenum-nickel-iron, 1 cobalt-nickel-iron, and molybdenum-aluminum-iron alloys have been prepared together with pure nickel and pure iron. A magnetite crystal has been obtained from an outside source. The magnetostriction and anisotropy constants of the above alloys have been measured; in addition, for those systems showing disorder effects, these constants have been measured for both the ordered and disordered states. New data are reported on some of the alloy systems not previously available in the literature. Preliminary analysis indicates good agreement with some of the older data. However some of the data differ considerably from that previously reported--particularly, the anisotropy constants originally obtained from magnetization curves.

WAPD-Res-13

Ruffennach R L
INFORMATION PERTAINING TO THE USE OF THERMOCOUPLES IN HIGH NEUTRON FLUX,
Westinghouse Electric Corp., Atomic Power Division, Bettis Field, P.O. Box 1468, Pittsburgh 30, Pa., May 24, 1954, 2 pp.

This is a letter concerning the subject-information pertaining to the use of thermocouples in high neutron flux. The letter points out that, based on available information, no appreciable effect on the thermoelectric properties of a thermocouple results when exposed to 10^{14} n/cm^2/sec.

Irradiation has an adverse effect on the insulation properties of most materials. As of this date, insulation materials that have proven satisfactory are magnesium oxide, aluminum oxide, lava, and ceramic insulation produced by the Stupakoff Company of Latrobe, Pa.

Glass and asbestos are satisfactory insulators for room temperature, but fail at higher temperatures. As of this date, no flexible insulation has been found that will hold up under irradiation.

WAPD-RES-13

Palladino N J
INFORMATION PERTAINING TO THE USE OF THERMOCOUPLES IN HIGH NEUTRON FLUX,
Westinghouse Electric Corp., Reactor Dept., Small Reactors Subdivision, Bettis Field, P.O. Box 1468, Pittsburgh 30, Pa., May 24, 1954, 2 pp.

This document concerns the effect of neutron flux on thermocouple calibration and insulating materials.

WAPD-STR(Ph)-83

Russ William
NEUTRON BOMBARDMENT EFFECTS IN SEMICONDUCTORS,
Westinghouse Electric Corp., September (1955), 23 pp. (25 refs).

This report covers the theory of neutron bombardment in semiconductors.

Experimental work was done and reported here.

High energy radiations may bring about extensive changes in the properties of solid substances. In particular, fast massive particles (alpha particles, protons, deuterons, neutrons, fission fragments, and to a certain extent electrons) possess sufficient momentum to produce atomic displacements directly and, hence, induce effects in solids at all temperatures. Consequently, radiations of this type may be expected to induce atomic rearrangements in materials which are normally very stable and would not be influenced readily by particles possessing a low momentum.

It is evident, therefore, that the properties of any solid will be drastically altered if an appreciable fraction, say, 10%, of its atoms are displaced and if the back diffusion of displaced atoms is not sufficiently rapid to undo the influence of the displacements.

The fundamental theory of radiation effects centers around the laws of energy dissipation of a fast charged particle as it moves through a lattice. Radiation effects are conveniently grouped into two quite distinct categories, namely, ionization effects and displacement effects.

WCRT-TN-54-255

Young Robert C
GAMMA IRRADIATION OF CRYSTAL DIODES,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December (1954), 6 pp.

This report outlines the progress on studies concerning the effects of nuclear radiation on semiconductor components. In general, there is an increase in back current, when the diodes are placed in gamma radiation, which returns to normal upon removal if the dose is low. No change is observed in the forward curve. Above a certain dose (which was much higher for the silicon 1N137 diodes than the germanium 1N83), the diode held up as long as irradiation continued, but deteriorated upon removal. There seems to be a concurrent increase in forward resistance, but this seems to be negligible until after the decrease in reverse resistance makes the diode unusable.

25

ZIF-0756-1

Rozman I M and Tsimmer K G
INVESTIGATION OF THE ELECTRIC CONDUCTIVITY OF INSULATING MATERIALS BEFORE, DURING, AND AFTER IRRADIATION,
Zhurnal Teknicheskoi Fiziki, Vol. 26, pp. 1634-1641, July-December (1956), (18 refs).

A new and simple method is described for measuring the electric conductivity of insulating materials before, during, and after subjection to ionizing radiation, and for measuring the temperature dependence of the conductivity. This method is used to perform measurements on compressed amber, polystyrene of various purities, polymethyl methacrylate, polyethylene, and polychlortrifluorethylene.

METALS, ALLOYS, AND CERAMICS

METALS, ALLOYS, AND CERAMICS

A/Conf. 15/P/614

Nightingale R E, et al.
DAMAGE EFFECTS TO GRAPHITE IRRADIATED UP TO 1000°C,
Hanford Atomic Products. Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 13 pp. (15 refs).

The effect of reactor irradiation on polycrystalline graphite at room temperature was reported during the 1955 Geneva Conference. Changes in properties with neutron exposure at 30°C are now quite predictable. Although the fundamental processes in such a complex system are far from being well understood, considerable progress has been made in this area, and a description of radiation damage in graphite has been developed. The irradiation effects in graphite above 30°C are less well known. A limited amount of data up to 200°C has been reported. This paper extends the 30°C irradiation data reported previously to higher exposures, describes the effect of long-term irradiations at 400° to 500°C and presents a limited amount of data from irradiations at 600° to 1050°C. An interpretation is suggested for some of the damage effects observed.

A/Conf. 15/P/1878

Bartz M H
PERFORMANCE OF METALS DURING SIX YEARS SERVICE IN THE MATERIALS TESTING REACTOR,
Phillips Petroleum Company. Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 23 pp.

The MTR has operated for six years without a single failure of equipment that can be attributed solely to the effects of radiation changing properties of the metals used in its structural and fuel components. The fact that the MTR to date has not been troubled by failure of components does not mean that its future will be as pleasant nor does it mean that other reactors will be trouble free in this respect. The properties of materials used in reactor core construction are changing constantly and surveillance programs should be in effect, in any reactor operation, by which it is possible to determine changes in properties that may result in equipment failure. As more and accurate information covering long-time effects of radiation on materials properties becomes available, it may be possible to design reactors, with complete assurance of long-time satisfactory operation. Unfortunately, that satisfying condition does not exist with today's information on radiation damage to metals and alloys.

A/Conf. 15/P/1978

Wilson J C
EFFECTS OF IRRADIATION ON THE STRUCTURAL MATERIALS IN NUCLEAR POWER REACTORS,
Oak Ridge National Laboratory. Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 26 pp. (26 refs).

Structural and nonfissile metals are among the least sensitive of materials to radiation effects that would injure their engineering properties for use as reactor components. There are instances, however, where the engineering properties of metals are adversely affected by irradiation. The problem of evaluating the influence of irradiation effects is difficult because there are still very few data; the influence of a number of irradiation and material variables is unknown; some data suggest that irradiated materials have distinctly different, if not new, properties compared to unirradiated materials; and because the exact exposure conditions of metals in service in power reactors are not well known.

The greater part of this paper will be concerned with the effects of irradiation in pressure vessel materials. In addition, the general nature of radiation effects in the face-centered cubic metals and alloys will be described.

A/Conf. 15/P/2385

Holmes D K, et al.
ON THE INTERPRETATION OF RADIATION EFFECTS IN THE NOBLE METALS,
Oak Ridge National Laboratory. Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958). 20 pp. (30 refs).

Since 1950 there has been a concerted effort to understand the nature of the changes produced by radiation in the noble metals, particularly copper, at low temperatures. The analysis of the experiments has encountered many difficulties and ambiguities which have made it possible for a number of independent schools of opinion to develop. An attempt to summarize some of the points of view in conjunction with a survey of the quantitative aspects of the subject of radiation effects in solids was presented at the 1955 Geneva Conference and published in more complete detail early in 1956. In the meantime, several decisive experiments have been carried out which have clarified a part of the picture. This report attempts to survey the present status of the topic even though uncertainties still persist.

AD-337(c)

Shelberg W, et al.
CHEMICAL DECONTAMINATION OF STAINLESS STEEL AND 24ST ALCLAD ALUMINUM,
Final Report, Technical Objective AW-5c. Applied Research Branch, Chemical Technology Division, U.S. Naval Radiation Defense Laboratory, San Francisco 24, California, July 24, 1951. 24 pp. (8 refs).

Comparisons are made regarding the abilities of a number of surface active agents, complexing agents, commercial detergents, and mixtures of these materials to decontaminate surfaces of stainless steel and alclad aluminum (24ST) contaminated with neutral mixed-fission-product contaminant (strontium, yttrium, zirconium and niobium); comparisons are made at room (20-5°C) and steam cleaning (70-6°C) temperature. Several reagents are quite efficient at room temperature, and a tendency for an increase in decontamination with an increase in temperature is frequently noted. Graphs define the dependency of decontamination upon pH at both temperatures for stainless steel and alclad aluminum.

AD-25302

Epstein Benjamin (Project Director)
OUTLINE OF RESEARCH IN LIFE AND FATIGUE TESTING,

Final Report, April (1951) - January (1954), Department of Mathematics, Wayne University, Detroit, Mich., Contract Nonr-451(00)(NR-042-017), 24 pp. (45 refs).

On April 1, 1951, a research project on the statistics of life and fatigue testing was initiated at Wayne University. The principal objective of the research was to develop statistical techniques of estimation and decision making which make maximum use of the information arising from life and fatigue tests. A characteristic feature of such tests is that information becomes available continuously and failures, when they do occur, are naturally ordered. In the course of this research, statistical procedures were developed, in life testing, which are optimum.

The research done under this project represents substantial progress in a field about which little was known two to three years prior. On the theoretical side, fundamental work was done in estimation and hypothesis testing, in stochastic processes, continuous and ordinary sequential analysis, nonparametric theory, and order statistics.

The report covers personnel on the project, reports and papers resulting from the project, summary of the results obtained under the project, related work by other mathematical statisticians, and some remarks on the application of this work.

AD-89451 ARC-3694

THE EFFECTS OF RADIATION ON MATERIALS,
Report Bibliography, Compiled by ASTIA Reference Center, Library of Congress, Washington, D.C., February (1956), 13 pp.

This bibliography is a reproduction of catalog cards which refer generally to the immediate holdings of the Armed Services Technical Information Agency, Reference Center, Library of Congress, on the indicated subject.

In most cases these reports have originated from the government-sponsored research program and, unless they have appeared in published literature, are in turn available only to that program. Contractors requesting reports should indicate the contractual connection in which they are needed. Requests for reports should be sent to the Armed Services Technical Information Agency, Dayton, Ohio. Requests from the Washington, D.C. area should be sent to the ASTIA Reference Center, Technical Information Division, Library of Congress.

For TIP reports, the number which appears in the upper left-hand corner is sufficient identification. For reports not bearing TIP or AD numbers, the request should be made by the issuing agency and the contract number. The distribution of the reports will be governed by the classification of the report.

This bibliography contains reference information pertaining to alkali halide crystals, crystals and semiconductors, glass and optical materials, metals and alloys, organic compounds, packaging materials, photographic film and emulsions, and plastics and elastomers.

AD-93436 ARC-3694 Suppl 1

THE EFFECTS OF RADIATION ON MATERIALS,

A Report Bibliography, ASTIA Reference Center, Library of Congress, Washington, D. C., April (1956), 10 pp. (66 refs).

This is a report bibliography which contains reference information pertaining to glass and optical materials, inorganic compounds, metals and alloys, organic compounds, photographic film and emulsions, and plastics and elastomers.

AECD-3095

Blewitt T H and Coltman R R, Jr.
THE EFFECT OF REACTOR IRRADIATION ON THE STRESS-STRAIN CURVE OF COPPER, (Copy available in Sandia Corporation Library), 4 pp.

A single crystal of copper was grown under high vacuum by the Bridgeman method. The copper was irradiated to a fast flux of about 2×10^{18} nvt. A stress-strain curve of the copper crystals before and after irradiation is shown.

AECD-3454 ANL-4790

Untermyer S and Weills J T
HEAT GENERATION IN IRRADIATED URANIUM,
Argonne National Laboratory, Chicago 80, Ill., Contract W-(31-109)-Eng-38, February 25, 1952, 20 pp. (13 refs).

This report presents data on the heat generated in irradiated uranium. Results are presented both as curves and formulae. The data cover the range between 10^{-1} and 10^{8} seconds.

Heat is produced in uranium from the following causes after a chain reaction is stopped:

1. Fissions from delay neutrons
2. Decay of radioactive fission products
3. Decay of U-239 and Np-239

Determination of decay heating can be made in two ways:

1. Radiochemical: by measuring the number of disintegrations.
2. Calorimetric: by measuring heat produced by radioactive decay.

Appendix I - A and B are included which cover "A Calorimetric Measurement of Fission Product Heating in a Uranium Rod", and "Radioactive Decay of Fission Products," respectively.

Appendix II - Steinberg, E P, "Power Decay of Fission Products."

AECD-3679

Spalaris C N
ADSORPTION PROPERTIES OF VIRGIN AND IRRADIATED GRAPHITE,
Hanford Atomic Products Operation, Richland, Washington, Contract No. W-(31-109)-Eng-52, November 24, 1954, 85 pp. (Bibliography; 29 refs).

The introduction discusses theoretical considerations of the experimental problem, general characteristics of the graphite used in the experiments, and radiation flux used for sample exposure. The report consists of additional sections on experimental methods: experimental results; surface characteristics of virgin graphite; surface characteristics of irradiated graphite; discussion of experimental findings; and conclusions.

Graphite is a crystalline solid whose importance occupies a prominent position in the development of atomic energy. The use of graphite as moderator material in atomic reactors has necessitated a large quantity of information concerning the effects of radiation flux on its physical and chemical properties. Research undertaken at various laboratories dealt primarily with the effects of radiation flux on physical properties of graphite such as dimensional characteristics, electrical resistivity, thermal conductivity, Hall coefficient, crystalline structure and stored energy. All of these properties undergo significant changes when graphite is subjected to radiation flux, and in particular energetic neutron flux.

One of the most important effects induced by neutron irradiation on graphite, in a low-temperature (20^{o}-100^{o}C) environment, is the changes of its physical dimensions.

AECD-3796

Cooper E P and Mills M M
THE POSSIBILITY OF FREEZING-IN RADIATION DAMAGE EFFECTS IN SIMPLE METALS, North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, June 20, 1950. 11 pp. (8 refs).

The desirability of observing radiation damage effects in simple metals has led to the suggestion that damage could be "frozen-in" by conducting experiments at low temperature. Vand's data has been utilized to estimate the necessary low temperature for a number of metals, with the result that exposures at solid CO_2 temperatures will probably be adequate in many cases and experiments conducted at liquid air temperatures will almost certainly be successful. This conclusion is supported by experimental data for copper, for which damage effects have been retained at ~100^{o}K.

This report is based on studies conducted for the Atomic Energy Commission under Contract AT-(11-1)-Gen-8.

This report, although not conclusive, provides combined experimental-theoretical indications that radiation damage may be "frozen-in" at low temperatures in simple metals.

AECD-3928

Faris F E
RADIATION EFFECTS QUARTERLY PROGRESS REPORT, JANUARY - MARCH, 1954, Atomic Energy Research Department, North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, August 15, 1954, 48 pp. (22 refs).

This report discusses the following topics relative to graphite: thermal conductivity of graphite; thermal conductivity of Brom-Graphite residue compounds; field dependence of the Hall Coefficient and the Magneto Resistance of irradiated graphite; cyclotron irradiation of graphite; and asymptotic aging experiments.

Relative to metals the following topics are discussed: cyclotron irradiation of thorium, uranium, and gold 3% thorium; annealing studies of cold-worked and irradiated thorium; X-ray diffraction; imperfections in copper in terms of electrical resistivity and thermoelectric power; and elastic constants and internal friction.

In addition to these, radiation damage in insulators, cyclotron operation, and statitron operation is discussed.

AEC-TR-3210

Zakharov A I and Maximova O P
THE INFLUENCE OF NEUTRON IRRADIATION ON MARTENSITE TRANSFORMATIONS, Translated from Russian by S. J. Rothman, Central Scientific Research Institute of Ferrous Metallurgy, 4 pp. (16 refs).

This paper describes the effect of in-pile irradiation of the order of 10^{17} neutrons per cm^2 on several steels, some of which were austenitic. The irradiation increased the intensity of the martensite transformation which followed the deep cooling. In the case of the manganese steel, some transformation occurred under radiation.

The activation effect of the austenite was removed by aging and by low temperature annealing. A theory of activation is postulated, explaining some of the effects in terms of exposure.

AECU-2906

Wruck D and Wert C
THE ROLE OF CRYSTAL STRUCTURE AND IRRADIATION EFFECTS ON MATERIALS, University of Illinois, Urbana, Ill., April (1955), 24 pp.

The resistivity of iron has been determined to increase more than that of cobalt and nickel when these metals are bombarded at -1500°C by 12 Mev deuterons. The same effect was observed for iron and nickel by neutron irradiation at room temperature. This result may be interpreted as indicating that iron is affected to a greater extent than either cobalt or nickel by heavy particle bombardment, though other interpretations may also be made. Annealing of the cyclotron irradiated samples showed that a smaller fraction of the effect produced in iron remained a room temperature anneal than cobalt and nickel. Also bombarded were titanium and vanadium.

AECU-3684

Koehler J S, et al.
IRRADIATION DAMAGE AT LOW TEMPERATURES IN THE NOBLE METALS, Department of Physics, University of Illinois, Urbana, Ill., Contract No. AT(11-1)-182, May (1958), 26 pp. (22 refs).

This report is a survey which attempts to assess the knowledge in the field of irradiation damage at low temperatures in the noble metals.

At present there is every reason to believe that the damage introduced into a metal by nuclear irradiation consists of clusters each containing interstitials and vacancies plus some close pairs. The simple theory of damage using a discrete displacement energy

predicts amounts of damage which are too large. There are three possible reasons for the discrepancy. First, the agitation of it, particularly in close pairs. Second, the assumption of a single discrete displacement energy is probably an over-simplification which may not be allowable. Third, if focussing is important then much of the theory involved in the calculation of v, the total number of displacements per primary, will require revision. At present the third possibility seems unlikely in copper because reasonable numbers of close pairs are found.

AERE-C/M-290

Sangster D F
THE GASES EVOLVED DURING THE DECOMPOSITION OF ANTHRACENE BY FISSION FRAGMENTS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, September (1957), 7 pp.

A mixture of anthracene and uranium dioxide has been irradiated in the Harwell pile BEPO. The gases evolved were collected, measured and analysed. G values found for the mixture were: hydrogen 0.38, acetylene 0.09, ethylene 0.04, methane 0.01. These values decreased as the irradiation continued and possible reasons for this are given.

AERE-C/R-345

Wright J and Brook D W
EXPERIMENTS ON THE STRENGTH OF GLASS AFTER FAST NEUTRON IRRADIATION,
Atomic Energy Research Establishment, Harwell, Berkshire, England, May (1949).

Thin rods of various glasses were irradiated inside a hollow uranium cylinder near the centre of G. L. E. E. P. They were then tested to destruction by loading the mid point of each rod while it was supported horizontally on two knife-edges. The results of these tests were compared with those on similar unirradiated glass rods. Soda glass, lead glass, Phoenix, Pyrex, Hysil and fused silica were studied.

AERE-Lib/Trans-584

Zimen K E and Schmeling P
THE DIFFUSION OF NOBLE-GAS FISSION PRODUCTS IN URANIUM,
Atomic Energy Research Establishment, Harwell, Berkshire, England, (1955), 4 pp. (2 refs).

A range of isotopes of krypton and xenon is formed as fission products when uranium is irradiated with neutrons. The diffusion of these atoms of noble gases in metallic uranium is of interest in connection with the operation and control of nuclear reactors. Some results are communicated in respect of the diffusion of Xe^{133} in uranium.

AERE-M/R-2305

Thompson M W
THE STRENGTH OF SILICA GLASS AFTER PILE IRRADIATION AT 100°C AND -196°C,
Atomic Energy Research Establishment, Harwell, Berkshire, England, June (1957).

The strength of silica glass rods, measured at -196°C, has been observed after irradiation in BEPO at 100°C and at -196°C. No changes greater than 10% were observed after 2.4×10^{18} n/cm^2 at +100°C or after 1.6×10^{18} n/cm^2 at -196°C.

AERE-M/R-2515

Churchman A T, et al.
THE TENSILE PROPERTIES OF STEEL IRRADIATED WITH NEUTRONS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, March (1958).

The tensile properties of En^2 structural steel have been measured before and after irradiation with neutrons to a maximum dose of 9.1×10^{19} n/cm^2. The effect of grain size and testing temperature on the yield and fracture strengths have been determined.

The results have been analyzed in the light of Cottrell's relation for the transition from ductile to brittle fracture.

AERE-M/R-2536

Burnett R C, Allen J M W and Harries D R
THE EFFECTS OF NEUTRON IRRADIATION ON THE DUCTILE-BRITTLE TRANSITION TEMPERATURES OF WELDABLE STRUCTURAL STEELPLATE--EXAMINATION OF A WELDED DUCOL W-30 STEEL PLATE OF 4-5/8 INCH THICKNESS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, April (1958).

Neutron irradiation effects on the notched-bar properties of a 4-5/8 in. thick welded Ducol W. 30 steel plate are described. Notched specimens machined from various levels in the parent plate and weld metal were irradiated to integrated neutron doses of 4×10^{19} n/cm^2 at both 50° to 60°C and 130° to 140°C and tested in slow bend.

AERE-M/R-2555

Hull D and Mogford I L
ESTIMATION OF THE INCREASE IN NOTCHED IMPACT TRANSITION TEMPERATURE OF STEELS IRRADIATED WITH NEUTRONS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, April (1958).

The method, developed by Cottrell, of estimating the increase in notched impact transition temperature, ΔT, with irradiation dose, ϕ, from tensile experiments is described. The value of the constant $\Delta T/\phi$ 1/3 is calculated for four grain sizes of En^2 steel. There is reasonable agreement between the estimated values and experimental results. The value of this method of determining the sensitivity of steels to radiation embrittlement is emphasized and the experimental work required to produce the data is outlined.

AERE-M/R-2582

Makin M J
WORK SOFTENING IN IRRADIATED COPPER,
Atomic Energy Research Establishment, Harwell, Berkshire, England, May (1958).

The temperature dependence of the flow stress of polycrystalline copper, both unirridiated and after neutron irradiation, has been investigated by repeated tensile testing first at one temperature and then at another temperature. In this way reversible and irreversible temperature effects can be separated.

AERE-M/TN-27

Glen J W
A SURVEY OF RADIATION EFFECTS IN METALS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, July 15, 1954, 63 pp. (177 refs).

The unclassified literature on the various effects which irradiation with nuclear particles has on the properties of metals is surveyed. Effects in other materials have been included where they help to explain those in metals. Subjects dealt with include the nature, theory and annealing of radiation damage; the effects on the electrical resistance of pure metals and alloys and their annealing; radiation effects on the properties of semiconductors, and on the mechanical properties of metals, radiation induced phase changes; effects on X-ray and electron diffraction patterns. The experimental data are summarized in a table.

AERE-M/TN-28

Levy M
RADIATION COLORATION IN GLASSES,
Atomic Energy Research Establishment, Harwell, Berkshire, England, December 3, 1954. 6 pp. (35 refs).

Radiation coloration in ordinary glasses has been proposed as being due to a superposition of several absorption bands, each one having characteristics similar to those of an alkali halide F-band. The centres in glass are called G-centres and each centre is proposed as being due to an electron trapped at an oxygen ion vacancy in the neighbourhood of a particular group of one of the many cations in the glass.

Inhibition to coloration may take place by the addition of specific amounts of a high valent cation to the glass melt while sensitization occurs when very low additions are made. These phenomena are similar to those observed in the alkali halides and models have been proposed by the author to explain them in the case of glasses.

AGC-AE-17

Higgins H M
THE REACTION OF MOLTEN URANIUM AND ZIRCONIUM ALLOYS WITH WATER,
Aerojet-General Corporation, Underwater Engine Div., Underwater Fuels Sect., Azusa, Calif., Contract No. AT-(04-3)-44, April 30, 1956, 48 pp.

The molten metals uranium and aluminum and alloys of uranium-molybdenum, uranium-zirconium, and zircaloy-B were dispersed in water in order to determine if the reaction of these materials would go to completion and if the reactions were explosive in character. Test data substantiated predictions based on theory that droplet size and metal temperature were important factors in determining the extent and violence of the reactions.

Zirconium-base alloys were found to react violently under certain conditions, whereas uranium and uranium alloys reacted less violently under the same conditions. Small percentages of beryllium were added to zircaloy-B in an effort to reduce its reactivity. This effort was successful in that several of the resulting alloys were less reactive.

ANE-0858-1

Makin M J
HOW RADIATION DAMAGES METALS,
Atomics and Nuclear Energy, Vol. 9, No. 8, pp. 260-263, August (1958), (23 refs).

Many subjects which were formerly studied for academic interest are now essential to the success of the nuclear power program. One of these is the effect of radiation on solids. Extensive research is now under way involving attempts to understand and avoid radiation damage. The effects of subjecting metals to high energy radiation are discussed here, from both the theoretical and practical aspects. Four different ways are described in which a fast particle can interact with a metal.

ANL-4642(Del) AECD-3923

Hennig G R and Kurs A F
CARBON 11 TRACER EXPERIMENTS ON THE FATE OF DISPLACED CARBON ATOMS IN GRAPHITE,
Argonne National Laboratory, Chemical Div., Lemont, Ill., Contract No. W-(31-109)-Eng-38
June 29, 1951, 21 pp. (14 refs).

Radiation-damaged graphite containing radio active displaced carbon (C^{11}) atoms has been prepared by cyclotron or betatron irradiation.

The irradiated samples were annealed, and the distribution of radiocarbon was then determined by controlled combustion of the graphite.

It was concluded that a considerable fraction, possibly all, of the recoil displaced atoms annealed to the discontinuities surrounding the perfect regions within the graphite particles. This annealing appeared to be complete at temperatures below 750°C.

These investigations have been temporarily interrupted since sufficiently high energy gammas or neutrons are at present unavailable.

ANL-5481

Primak W L and Quarterman L A
THE HYDROLYSIS OF THE COMPOUND OF POTASSIUM WITH IRRADIATED GRAPHITE,
Argonne National Laboratory, Chemistry Div., P. O. Box 299, Lemont, Ill., Contract No. W-(31-109)-Eng-38, September 12, 1955, 6 pp. (6 refs).

Potassium, the reaction product of graphite with potassium, and the reaction product of irradiated graphite with potassium were subjected to hydrolysis. The gases evolved from the respective samples were analyzed mass spectroscopically. Hydrocarbons (methane and a trace of ethane) were found in the gas evolved from the irradiated graphite compound only, and the quantity was about that which would have been expected from the number of nonaggregated displaced atoms. The result was obtained for a single set of experiments and must be considered suggestive rather than conclusive.

ANL-5537

Paine S H, Brown F L and Murphy W F
PRELIMINARY STUDIES OF IRRADIATION DAMAGE TO URANIUM-ZIRCONIUM ALLOYS, Argonne National Laboratory, Metallurgy Div., P.O. Box 299, Lemont, Ill., Contract No. W-(31-109)-Eng-38, October (1956), 28 pp. (Bibliography-4 refs).

The addition of zirconium to uranium is shown to have a beneficial effect upon the irradiation stability of the fuel alloy. Preliminary methods used to discover this fact, and experimental problems encountered are described in this report.

ANL-5706

Kittel J H and Kelman L R
EFFECTS OF IRRADIATION ON SOME URANIUM-PLUTONIUM ALLOYS, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-(31-109)-Eng-38, June (1958), 23 pp.

Irradiations were made on a number of uranium-plutonium alloy specimens from both cast and extruded materials. The cast alloys included alloys of uranium with 3.7, 6.6, and 13.0 w/o plutonium, and the extruded alloys included alloys of uranium with 9.5, 14.1, and 18.7 w/o plutonium. One-half of the extruded specimens were given a heat treatment consisting of heating to 645°C and cooling to and holding at 500°C for one hour in an attempt to remove the preferred orientation that was anticipated from extrusion. The specimens were irradiated to burnups ranging up to 0.84 a/o (7100 MWD/T) with central temperatures ranging up to 490°C. The cast specimens were all found to have developed severe surface roughening as a result of the irradiation they received, presumably because of excessively large grain sizes present before irradiation. Identically fabricated unalloyed uranium specimens showed similar behavior. The as-extruded alloy specimens maintained good surface smoothness under irradiation, but showed elongations which were dependent on plutonium content. For example, in samples with 0.4 a/o burnup, a 14.1 w/o plutonium alloy specimen elongated 96%, whereas an 18.7 w/o plutonium alloy specimen elongated only 8.4%. The heat-treated extruded specimens did not elongate anisotropically, indicating that the heat treatment used was effective in randomizing the grain orientation. However, the heat-treated specimens developed excessive surface roughening, apparently because the heat treatment caused an undesirably large grain size.

ANL-5825

Bailey R E
IRRADIATION EFFECTS ON ZIRCONIUM-CLAD URANIUM-ZIRCONIUM FUEL PLATES, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-(31-109)-Eng-38, February (1958), 10 pp.

This report summarizes the series of irradiations conducted in a Hanford reactor on specimens of zirconium-clad, uranium-zirconium fuel plates containing 3, 6, and 14 wt-percent highly (93.4%) enriched uranium. More than 30 fuel plates were exposed during the test program, which extended over a period of several years.

ANL-WMM-1140

Fields Paul and Weiss Molly Ann
THE COMPOSITION OF PLUTONIUM, AMERICIUM, AND CURIUM RESULTING FROM IRRADIATION OF AM^{241} IN A HIGH NEUTRON FLUX,
Argonne National Laboratory, Lemont, Ill., Contract No. W-(31-109)-Eng-38, February 20, 1953, 7 pp.

The isotopic composition of Americium, and to some extent, the plutonium and curium formed in a high neutron flux bombardment of Am^{241} have been calculated using the latest neutron cross-section data. All the calculations assumed that the starting material was one gram of Am^{241} and that it was exposed to a flux of 2×10^{14} nv. The calculations were carried out using the general equation given in ANL-WMM-1029. The major components of the plutonium and curium fractions from the Am^{241} irradiation were also calculated where sufficient data on cross sections was available.

BMI-962

Hedden W A, et al.
EXPERIMENTAL CARBONS AND GRAPHITES FOR IRRADIATION STUDIES,
Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio,
Contract No. W-(7405)-Eng-92, October 26, 1954, 46 pp. (3 refs).

As part of a program to study the effect of the constitution of graphite on its stability under neutron irradiation, test specimens were made from a broad selection of raw materials and by a variety of fabrication and processing techniques. Data on the raw materials, techniques of fabrication, and properties of the test specimens are given in this report.

The raw materials selected for study included the conventional, easy-graphitizing cokes, laboratory cokes made from commercial asphalts and pitches, carbon blacks, and cokes made from phenolic resins and cane sugar. The techniques used in processing the raw materials, fabrication, and heat treatment were varied to produce test specimens having a wide range in physical properties and in structural characteristics. The bulk density of specimens was found to depend on type of filler, type of binder, and processing variables.

Fifty-four groups of test specimens were submitted to Hanford for exposure to neutron irradiation. The effect of irradiation exposures, and correlations of radiation damage with properties of the specimens, will be given in a future report.

BMI-980

March L L, Muehlenkamp G T and Manning G K
EFFECT OF HYDROGEN ON THE TENSILE TRANSITION IN URANIUM,
Battelle Memorial Institute, Columbus, Ohio, Contract No. W-(7405)-Eng-92, February 14, 1955, 15 pp. (4 refs).

A study has been made of the effect of hydrogen and heat treatment on the ductility transition in alpha uranium. A transition from ductile to a semibrittle behavior in tension has been observed in the temperature range 75° to approximately $150^{\circ}F$. The transition is sensitive to residual strain, strain rate, hydrogen content, and to a smaller extent to heat treatment. On the basis of the data available, the transition appears to be similar

to transitions observed in other metals not of the face-centered-cubic type, and is not the result of hydrogen embrittlement. The effect of hydrogen in the composition range 0.3 to 4.7 ppm hydrogen seems to be observed principally in the values for reduction in area. At 4.7 ppm hydrogen, the amount of necking, i.e., the reduction of area, at fracture is noticeably less than for material that has been dehydrogenated.

BNL-2257

Hittman F and Kuhl D A
INITIAL STUDIES ON THE EFFECT OF HIGH LEVEL GAMMA RADIATION ON CORROSION OF METALS,
Brookhaven National Laboratory, Upton, N. Y., July (1955), 24 pp. (10 refs).

Detailed analysis of the effects of radiation on various materials and chemical compounds has been made. The results of these studies are discussed.

The results of initial studies on the effect of high level gamma radiation on 24ST aluminum in tap and distilled water at room temperature, 1020 mild steel in fused $NaNo_3$ at 350°C, copper in 2N HCl, and 1020 mild steel in 2N HCl are presented and discussed.

ER-6119 AD-34029

Moller Marx D
INDUCED RADIOACTIVITY OF SOME STRUCTURAL ALLOYS,
The Glenn L. Martin Co., Baltimore 3, Md., January (1954), 16 pp. (2 refs).

A designer of nuclear-powered vehicles is faced with the problem of evaluating the behavior of materials which are exposed to the radiation from an operating nuclear reactor. This evaluation must include the consideration of changes in the physical and mechanical properties of the material, and any tendency to exhibit induced radioactivity after the reactor has ceased operating.

This report concerns itself with the metals and alloys commonly used in aircraft structures. These include alloys of aluminum, magnesium, titanium, nickel, and iron (including corrosion-resistant steels). Unclassified information available for these metals indicates that atomic radiation of the intensities investigated to date has a negligible effect on the physical and mechanical properties of their alloys. A tendency of some metals to show an effect akin to a small degree of work hardening has been found, accompanied by slight changes in electrical resistivity.

All of the metals studied, however, have the property of giving off a measurable and sometimes dangerous induced radiation after being exposed to reactor radiations. The intensity, type, and duration of this induced radioactivity depends on the intensity and duration of the primary radiation to which the metal has been exposed, the elements present in the alloy, and the time which has elapsed since the exposure.

In the alloys investigated, the radioactivity consists of beta particles, gamma rays, or a combination of the two. The beta particles have a considerable range in air, but protection against their effects can be afforded with protective clothing including masks and goggles. The gamma rays have an extremely long range and high penetrating power, and protection against their effects is difficult. If gamma rays are present, it will be necessary to wait until their activity decays to a safe level before approaching a structure which has been exposed to atomic radiation. By a proper selection of materials this

waiting time can be shortened to a period which will permit a practical maintenance schedule for the structure. With this in mind, the scope of this report is limited to an investigation of the gamma radiation from various alloys.

ER-7033-34

EFFECT OF GAMMA RADIATION ON FM-47 BONDED METAL-TO-METAL JOINTS AND SANDWICH PANELS,
The Glenn L. Martin Co., Materials Laboratory, Baltimore, Md., September 23, 1955, 38 pp.

This test was for the purpose of determining the effect of gamma radiation of 10^5, 10^6, 10^7, and 10^8 R on FM-47 adhesive bonded panels.

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The test results of 1/2 in. lap tensile shear specimens indicate no change in tensile shear strength at room temperature or 220°F as a result of irradiation.

Honeycomb flexure specimens were tested and the results show no change in room temperature flexure strength and an inconclusive variation at 220°F due to irradiation.

A test was performed to determine the effect of gamma radiation of 10^5, 10^6, 10^7, and 10^8 R on joints bonded with Shell 422 adhesive.

GI-0152-1

Otley Kurt O
EFFECTS OF HIGH-ENERGY RADIATION UPON GLASSES,
Glass Industry, Vol. 33, No. 1, pp. 24-27, January (1952), (42 refs).

This is a literature survey which discusses the effects of high-energy radiation upon glass.

GI-1050-1

Sun Kuan-Han and Sun Laura L
NEUTRON ABSORBING AND TRANSMITTING GLASSES,
Glass Industry, Vol. 31, No. 10, pp.507-515, October (1950),(21 refs).

In this article, the Glass Industry presents a comprehensive treatment, both theoretical and experimental, on "Neutron Absorbing and Transmitting Glasses," by Kuan-Han Sun, nuclear physicist and glass scientist. The article is believed to be the first on the subject ever to be published. The concept outlined enabled Dr. Sun to develop the first neutron glass four years ago, as well as more recent ones, and this article is the second in which the Glass Industry has presented fundamental information on the radiation absorption and transmission of glasses. The first paper on X-ray absorbing and transmitting glasses appeared in the December 1948 issue.

GI-1248-1

Sun Laura L and Sun Kuan-Han
X-RAY ABSORBING AND TRANSMITTING GLASSES,
Glass Industry, Vol.29, No. 12, pp.686-691, 714, 716, December (1948), (8 refs).

This paper discusses the absorption or transmission of electromagnetic waves of or thru a homogeneous substance. A general expression is given for this. The equation is a universal one and is applicable to radiations such as gamma-rays, X-rays, ultraviolet rays, though visible to long infrared rays. Tables and curves are included which present mass absorption coefficients of some oxides and oxygen.

HW-17538

Moore R H
THE ANALYSIS OF PILE IRRADIATED HYDROCARBONS WITH THE INFRARED SPECTROMETER,
Hanford Works, Technical Services Div., Analytical Sect., Richland, Wash., Contract No. W-(31-109)-Eng-52, April 20, 1950, 11 pp. (1 ref).

This work is being done in the hope that the results will shed light on the nature of the changes which occur in graphite upon irradiation in the pile.

Infrared analysis of irradiated samples of benzene, naphthalene, anthracene, phenanthrene, 1, 2-benzanthracene, pyrene, and 1, 2, 5, 6-didenzanthracene has been completed. A sample of irradiated anthracene has been analyzed chromatographically with results in excellent agreement with the infrared analysis. Combined chromatographic and infrared analysis show the presence of phenyl derivatives in the irradiation products from naphthalene, anthracene, and phenanthrene. The latter two are also found to contain naphthyl derivatives.

HW-38079

Kemper R S, Jr. and Kelly W S
THE EFFECT OF IRRADIATION ON THE MECHANICAL PROPERTIES OF ARC-MELTED BUREAU OF MINES ZIRCONIUM WITH VARIOUS DEGREES OF COLD WORK,
Hanford Atomic Products Operation, Engineering Dept., Pile Technology Sect., Richland, Wash., Contract No. W-(31-109)-Eng-52, July 29, 1955, 32 pp. (16 refs).

Data are presented to show the effects of cold-working and subsequent neutron irradiation on the tensile properties and hardness of arc-melted Bureau of Mines zirconium. Material in six initial states, annealed and with 10, 20, 30, 40, and 50% reduction in area by cold swaging, was irradiated at 50° to 60°C (120° - 140°F) to integrated thermal flux levels of approximately 5.7×10^{19}, 1.5×10^{20}, and 2.4×10^{20} nvt. The results of post-irradiation vacuum annealing at 250°, 300°, and 350°C (480°, 575°, and 660°F) of tensile specimens are given.

Increases in hardness and yield strength resulting from the irradiation were more pronounced in the annealed material and were progressively less at increasing levels of cold work. More uniform increases in ultimate strength and decreases in ductility were found. The radiation damage observed in the mechanical properties was essentially saturated at exposure levels investigated. Slight annealing of radiation induced increases in yield strength occurred in 100 hours at 250°C (480°F) and approximately 70% of the radiation damage was removed in 160 hours at 350°C (660°F). Recovery of the radiation damage in annealed, irradiated material was greater than recovery of strain hardening in 50% cold-worked, unirradiated material for the same annealing conditions.

HW-38991

Huenshen R E and Kaulitz D C
AN APPARATUS FOR OBTAINING THE TENSILE PROPERTIES OF IRRADIATED MATERIALS AT ELEVATED TEMPERATURES,
Hanford Atomic Products Operation, Engineering Dept., Pile Technology Sect., Richland, Wash., Contract No. W-(31-109)-Eng-52, September 14, 1955, 22 pp.

A tensile testing unit is described which permits the testing of highly radioactive specimens at temperatures up to 800°C (1475°F). The vacuum tensile furnace, mounted on a 60,000-pound Baldwin tensile machine, is constructed to permit the measurement of elongation by a newly developed optical instrument. Tensile elongation measurements of 50% with 1-inch gage length specimens make the unit a relatively long-range extensometer.

HW-39539

Mallett G R
MACROETCHING OF IRRADIATED URANIUM,
Hanford Atomic Products Operation, Engineering Dept., Pile Technology Sect., Richland, Wash., Contract No. W-(31-109)-Eng-52, October 17, 1955, 6 pp. (4 refs).

An electrochemical method, using a hydrochloric-phosphoric acid bath, has been developed which gives a good macroetch on uranium irradiated up to 1550 Mwd/At. No special surface preparation is required unless the abrasive cutoff wheel produces burn marks on the cut surface. The burn marks can be removed by grinding with a 600-grit cloth prior to electrochemical etching.

The sample is made of the anode in the etching bath at a current density of 500 amps/sq ft for 30 seconds, then 50 amps/sq ft for 10 to 30 minutes. To determine the necessary etching time, the etched surface may be observed at 10-minute intervals. After etching, the sample is cleaned in nitric acid and rinsed in water. By rinsing immediately in ethyl alcohol, and then in n-octyl alcohol, the etch is preserved for two hours, allowing sufficient time for macrophotography work to be done before surface oxidation obliterates the etch.

HW-39805

Wheeler R G and Kelly W S
IRRADIATION OF ZIRCALOY-2 IMPACT SPECIMENS CONTAINING HYDROGEN,
Hanford Atomic Products Operation, Metallurgy Research Subsection, Richland, Wash., Contract No. W-(31-109)-Eng-52, November 2, 1955, 6 pp. (3 refs).

The affinity of zirconium for all but the inert gases, a property that makes it valuable as a getter, causes some concern when zirconium or its alloys are used in a reactor where the metal is exposed to a gaseous atmosphere or to high temperature water.

Eighteen specimens were charged with hydrogen holding them in a 10^{-5} mm of mercury vacuum for one hour at 500°C and allowing them to soak up a measured amount of hydrogen and homogenize for four hours at 600°C.

The specimens were exposed to an integrated flux of 1.9×10^{19} nvt at 150° to 200°C in a pressurized water loop running through the central zone of the Hanford pile. The results were no detectable pickup of hydrogen in Zircaloy-2 specimens located both in and out of the central flux zone.

HW-40494

Merchx K R
A MODEL OF MECHANICAL BEHAVIOR EVALUATED WITH CREEP TESTS APPLIED TO ALPHA URANIUM,
Hanford Works Products Operation, Metallurgy Research Sub-Section, Pile Metallurgy Unit, Richland, Washington, November 17, 1955, 17 pp.

This report presents a model for the mechanical behavior of a metal which considers the stress, strain, time, and temperature dependence of strain-rate. The parameters in the model are evaluated with creep tests. A series of creep tests for uranium are analyzed to give an equation of mechanical behavior for uranium. The method applies for uranium in the temperature range of 100° to 300°C but must be modified in the higher temperature ranges.

HW-51444

Bush S H
IRRADIATION EFFECTS ON URANIUM,
Hartford Atomic Products Operation, Richland, Wash., Contract No. W-(31-109)-Eng-52, July 19, 1957, 47 pp. (45 refs).

A review is presented of pertinent physical metallurgical properties of irradiated uranium. Included under mechanical properties are hardness, bend, and tensile data. In the case of tensile properties, variables considered are burnup, irradiation temperature, U^{235} content, composition (to 3 w/o alloy), post-irradiation annealing, and tensile testing temperature. Drastic reductions in ductility occur at burnups as low as 0.02 atom percent. Recovery of damage is limited on post-irradiation annealing.

Changes in such physical properties as density, thermal conductivity, electrical resistivity, and modulus of elasticity are reported. Thermal conductivity decreases 10 to 15% at nominal burnups.

The effect of irradiation on the microstructure of uranium is reported. Macroscopic, optical and electron microscopic, and fractographic results are presented. Precipitation, microcracking, and microbrittleness were detected. Solid-state studies, including recrystallization, and solid and noble gas diffusion are reported. No direct evidence of a change in diffusion due to irradiation has been obtained.

Structural changes have been observed by means of X-ray diffraction; line broadening, line asymmetry, and some line shift have been observed.

Dimensional instability of uranium is discussed; typical results and possible mechanisms advanced to explain these results are reported.

The impact of these changes in physical metallurgical properties on the behavior of uranium fuel elements is discussed.

HW-52323

Kemper R S and Zimmerman D L
NEUTRON IRRADIATION EFFECTS ON THE TENSILE PROPERTIES OF ZIRCALOY-2,
Hanford Atomic Products Operation, Richland, Wash., Contract No. W-(31-109)-Eng-52, August 22, 1957, 24 pp. (12 refs).

The changes produced in the room temperature tensile properties of annealed and 50% cold-worked Zircaloy-2 as a result of irradiation to an estimated integrated thermal neutron flux of 1.4×10^{21} nvt at 40° to 60°C have been determined. The results obtained are compared with previous results on Kroll-type zirconium. Recovery of radiation damage in initially annealed material was studied in the temperature range 250° to 400°C. This recovery was found to require temperatures equivalent to those for recovery of cold work and the activation energy for the process was found to be consistent with that reported for self-diffusion in zirconium.

HW-52729

Evans E A
FABRICATION AND ENCLOSURE OF URANIUM DIOXIDE,
Hanford Atomic Products Operation, Reactor and Fuels Research and Development Operation, Richland, Wash., Contract No. W-(31-109)-Eng-52, September 18, 1957, 36 pp. (49 refs).

Uranium dioxide compacts of high density can be economically produced by conventional ceramic processes, such as cold pressing, isostatic pressing, hot pressing, extrusion, and slip casting. Greatly reduced costs and improved quality have been made possible by new powder treatments and fabrication techniques. Typical of the recent developments are (1) powder activation by reduction in a fluidized bed, (2) combined powder compaction and cladding by swaging, without subsequent sintering, and (3) finishing of sintered ware by belt centerless grinding.

To overcome the disadvantage of poor neutron economy, uranium dioxide fuel assemblies require not only high-density oxide, but also an efficient arrangement of the fuel. It is now economically feasible to fabricate uranium dioxide cores for relatively simple fuel assemblies which will meet this requirement.

Problems of providing safe, durable, economical enclosures for uranium dioxide fuel cores are rapidly being solved. Techniques have been developed for forming and assembling tubing, and fittings, and supporting members from alloys of zirconium, iron and aluminum. Less conventional techniques, such as vacuum casting of zirconium alloys and high-frequency welding, are being studied. Standardization of fabricating processes and fuel element designs is an extremely desirable objective which will be partially realized as the operating behavior of uranium dioxide fuel elements becomes better understood.

IDO-14347

Andelin R L and Anderson E L
RADIATION STABILITY OF CHROMIUM VI IONS IN ACETATE BUFFERED SOLUTIONS,
Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, August 22, 1955, 25 pp. (refs).

Chromium VI ions are reduced to trivalent chromium in acidic acetic acid-sodium acetate buffered solutions when subjected to intense gamma irradiations. The reduction rate of a 0.5M chromate solution buffered with 4.0 M acetate is 2.35 $\pm$ .15 millimoles per kilocalorie at pH 4 in a gamma field of approximately 10^7 roentgens per hour. The decomposition rate is reduced to 0.51 $\pm$ .15 millimoles per kilocalorie by the addition of 0.5M sodium bromide. The reduction rate is independent of intensity of irradiation, of chromate concentration in the range 0.05M to 0.5M, and of bromide concentration in the range 0.1M to 1.0M. It is a function of acetate concentration, however, and decreases

with decreasing acetate concentration in the range 4.0M to 0.1M. In a 0.1M chromate solution buffered with 0.1M acetate at pH 4.0 and containing 0.1M sodium bromide as a protector, the chromate reduction rate is 0.18 ± .03 millimoles per kilocalorie.

IDO-16162

Burnham J B and Bartz M H
DIMENSIONAL STABILITY OF IRRADIATED THORIUM,
Phillips Petroleum Co., Atomic Energy Div., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, April 13, 1954, 10 pp. (12 refs).

Twenty Hanford size thorium slugs were irradiated in two MTR reflector positions to a maximum exposure of 10^{21} nvt. Four slugs were sent to ORNL for measurement and the rest were checked in the MTR hot cell. Results of these measurements show that hot rolled thorium is dimensionally stable under irradiation.

IDO-16182

Fast E
GRAPHITE DAMAGE AS AN INDEX TO THE INTEGRATED DAMAGING NEUTRON FLUX,
Phillips Petroleum Co., Atomic Energy Div., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, September 28, 1954, 25 pp. (13 refs).

Radiation damage in CS-GBF graphite, as measured by changes in electrical resistivity, crystallite C_o spacing, physical dimensions, and stored energy, has been related empirically to the fast neutron flux above 1 Mev. The purpose of this work was to evaluate several properties of graphite as a possible index to damaging neutron flux in radiation damage studies. A brief summary of useful nvt range and standard deviation of points from the best-fit curve is as follows:

Property	Useful range nvt 1 Mev.	Standard deviation in relative error, percent
Electrical resistivity	3×10^{15} - 10^{18}	13.
C_o spacing	10^{18} - 5×10^{19}	9.8 3.1 (above 5×10^{16} nvt.)
Stored energy	10^{17} - 6×10^{18}	18.8 11.3 (above 10 cal/g)
Physical dimension	5×10^{18} —	15.2

In addition to having the best reproducibility, X-ray measurement of C_o spacing covers the range most frequently encountered in in-tank exposures at the MTR. Augmented by electrical resistivity and dimensional measurements, made on the same samples, both lower and higher exposures can be read.

Graphite radiation damage as flux monitor has the advantage of giving a value proportional to total damaging nvt. The relatively low activation, even for very high exposures, allows handling of irradiated specimens without special shielding.

IDO-16337

Robinson M S
RADIATION DAMAGE STUDIES PROGRAM ETR LOOP MATERIALS PROGRESS REPORT, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, April 19, 1957, 22 pp.

The design of experimental loops for the ETR has required the consideration of some structural metals for which there is little engineering data concerning the change of mechanical properties with neutron irradiation. Samples of these materials have been obtained and sub-size impact and tensile samples are now being irradiated in the MTR. From these samples changes in such properties as tensile strength, hardness, ductility, corrosion resistance and impact strength will be determined. The first group of tensile samples, consisting of: Hastelloy-X, Zircaloy-2, 410 Stainless Steel, 2-1/4 Croloy and Inconel-X, has been tested in the MTR hot cell. The 2-1/4 Croloy, which was nickel-plated before reactor insertion, corroded too much to permit further reactor testing. Test data for the other materials and photographs of the samples are presented.

IDO-16483

Watanabe H T and Schaffnit W O
RADIATION DAMAGE STUDIES OF BORON STAINLESS STEEL, Interim Report, Phillips Petroleum Co., Idaho Operations Office, Contract No. AT-(10-1)-205, September 18, 1958, 19 pp.

With the use of boron stainless steel in control rods in a reactor, it is important to know whether the operating conditions of temperature and radiation will effect changes in mechanical properties and dimensions and to know the magnitude of such effects if they occur. Tensile specimens of 18-8 stainless steel containing 1% boron, enriched to 93% in boron-10, were fabricated and irradiated in the Materials Testing Reactor to 15% and 25% burnup of boron-10. These were tested for tensile strength, hardness and elongation, and examined metallographically to observe changes in microstructure. The irradiated material was extremely brittle and areas that appeared to be vacancies were seen in the photomicrographs.

IDO-16502

Schaffnit W O
RADIATION DAMAGE STUDIES OF BORON STAINLESS STEEL FINAL REPORT, Phillips Petroleum Co., Atomic Energy Div., Contract No. AT-(10-1)-205, January 28, 1959, 27 pp.

With the use of boron stainless steel in control rods in a reactor, it is important to know whether the operating conditions of temperature and radiation will effect changes in mechanical properties and dimensions and to know the magnitude of such changes if they occur. Tensile specimens of 18-8 stainless steel containing 1% boron, enriched to 93% in boron-10, were fabricated and irradiated in the Materials Testing Reactor to 15% and 25% burnup and in the Engineering Test Reactor to 40% and 90% of the boron-10 isotope. These were tested for tensile strength, hardness and elongation, and examined metallographically to observe changes in microstructure. The irradiated material was extremely brittle, changes were noted in the microstructure, and a crack was discovered in one of the higher burnup specimens.

This is a final report and includes material previously reported in IDO-16483, titled "Radiation Damage Studies of Boron Stainless Steels Interim Report."

IU-TR-12

Vook Richard Werner
EXPANSION OF COPPER UPON LOW TEMPERATURE DEUTERON IRRADIATION,
Univ. of Illinois, Dept. of Physics, Urbana, Ill., Contract No. AT-(11-1)-192, September (1957), 31 pp. (26 refs).

The imperfections existing in crystalline solids greatly influences the properties of crystals. There are many ways in which these imperfections may be studied; one of these involves the use of high energy particle irradiation. This report discusses expansion of copper upon low temperature deuteron irradiation.

Irradiation effects generally fall into two categories; those occurring during bombardment and those associated with thermal recovery. Each gives useful information about the defects produced by irradiation. The amount and type of bombardment and the temperature of irradiation determine the concentration of defects produced. The maximum concentration for a given irradiation dosage will be obtained if the temperature of irradiation is kept low enough so that thermal recovery does not occur.

The experiment described in this report presents measurements of the length charge induced in high purity copper at 17°K by deuteron irradiation. It was demonstrated in two bombardments, one short and one somewhat longer, that the damage was introduced linearly with integrated deuteron flux. In addition, the annealing processes between the bombardment temperature and room temperature were studied.

JAP-0257-1

Meechan C J
ANNEALING OF COLD-WORKED COPPER BY ELECTRON IRRADIATION,
Journal of Applied Physics, Vol. 28, No. 2, February (1957), 4 pp. (5 refs).

Copper wires were cold worked at room temperature to approximately a 15% reduction in area and were then irradiated at temperatures between 100° and 150°C with 1.25-Mev electrons. The residual resistivity was observed to decrease as a function of exposure at temperatures above 100°C. The higher the temperature at which the irradiation was performed, the greater was the rate of resistivity decrease. From these data, it is concluded that one of the primary defects produced by electron irradiation becomes mobile in the temperature range, 100° to 150°C. It is suggested that interstitials and vacancies produced by the irradiation initiate a process which results in the annihilation of dislocations. From an analysis of the temperature dependence of the rate of decrease, a value for the activation energy for vacancy migration in copper has been deduced: 1.28 ± 0.10 ev.

JAP-0557-1

Hines R O
RADIATION EFFECT OF POSITIVE ION BOMBARDMENT ON GLASS,
Journal of Applied Physics, Vol. 28, No. 5, pp. 587-591, May (1957), (12 refs).

Bombardment of a silica-soda-lime glass (n_D = 1.5246) by more than 5 x 10^4 A^+ ions/cm^2 with an energy of 33.5 kev reduces the reflection coefficient to 0.36 of its normal value for light of wavelength λ = 0.6μ. The change in reflection coefficient is attributed to the formation of an altered glass layer. For a bombardment by 40-kev A^+ ions, the layer has a thickness of 0.095μ and an effective refractive index of 1.343. The depth of the layer is determined by the ion energy and agrees approximately with the theoretical range of the incident ions. The refractive index of the altered layer is determined by the integrated flux of positive ions and the type of ion. The magnitude of the positive ion flux employed here is shown to be orders of magnitude larger than the flux of primary "knocked-on" atoms produced by fast neutron bombardment in a reactor.

JAP-0558

Mylonas C, et al.
BIREFRINGENCE IN NEUTRON-IRRADIATED BORON GLASS,
Brown Univ., Providence, R.I. Paper published in Journal Applied Physics, Vol. 29, pp. 864-865, May (1958).

Samples of boron glass were irradiated (slow flux approximately 2 x 10^{12} nv) in the Brookhaven Reactor for studies of the resulting ultrasonic attenuation and velocity changes. The plates invariably cracked after about an hour's irradiation; after irradiation for several hours they fell to pieces. Examined in polarized light incident normally on their largest faces, the plates showed little birefringence, but in an end-to-end viewing they exhibited relative retardation of several wave lengths. The disappearance of the birefringence in the neighborhood of certain stress-relieving cracks proved that the birefringence was caused by mechanical stress. There was evidence that the stress was tensile near the surface and compressive at the center. The dependence of the contraction on neutron flux can provide new information on the damage produced by energetic heavy particles in the interior of a solid and is the object of further investigation.

JAP-1258-1

Dienes G J and Damask A C
RADIATION ENHANCES DIFFUSION IN SOLIDS,
Journal of Applied Physics, Vol. 29, No. 12, pp. 1713-1721, December (1958), (25 refs).

A simple theory of radiation enhanced diffusion has been worked out which describes the dependence of this enhancement on flux and temperature under steady-state conditions. The theoretical study also shows that the measurement of enhanced diffusion as a function of temperature can indicate the mechanism by which defects are removed from the lattice. Alpha-brass was chosen for the experimental work because it is a kinetically simple system, not complicated by nucleation, in which diffusion is easily followed by measuring the electrical resistivity changes associated with changes in short-range order. The enhanced diffusion rate during irradiation in the Brookhaven reactor has been measured in this alloy at several temperatures in the range 0° to 190°C. This enhancement is independent of temperature from 0° to 150°C, in excellent agreement with the theoretical predictions for the case where the radiation induced defects finally disappear at internal surfaces. Some implications of radiation enhanced diffusion and suggestions for further study are also discussed.

JBNEC-0158

Cottrell A H
EFFECTS OF NEUTRON IRRADIATION ON METALS AND ALLOYS,
Atomic Energy Research Establishment, Harwell, Berkshire, England. Paper published in Journal of British Nuclear Energy Conference, Vol. 3, pp. 50-67, January (1958).

The behavior of metals and alloys under neutron irradiation in a reactor is investigated. An explanation of how damage originates from the collision and absorption of neutrons by nuclei, and a description of the behavior of the fast ions, produced from these neutrons encounters, as they penetrate the surrounding material are given. The estimated amount of damage is compared with measured values. Annealing of the damage in which displaced atoms gradually migrate back into lattice positions under the action of thermal agitation is discussed. The effects of irradiation on the mechanical properties of metals and alloys are discussed. Radiation growth in uranium and the effects of irradiation on the corrosion resistance of metals are discussed.

JM-0556-1

Wilson J C and Billington D S
EFFECT OF NUCLEAR RADIATION ON STRUCTURAL MATERIAL,
Journal of Metals, pp. 665-672, May (1956), (28 refs).

The properties of engineering interest in a wide variety of materials have been reviewed as they are known to be affected by irradiation. In addition, some of the possible implications of the property changes have been pointed out, and logical paths for future research have been deduced from the limited data at hand.

Attempting to predict the effects of radiation on metal is difficult, while changes from a few percent to perhaps a factor of three may occur in the various properties. It has, in many cases, been observed that the magnitude and direction of the change in these properties occur separately or independently in a manner that is new compared to the way the properties may be changed by variations in analysis, metallurgical practice, working or heat treating. Adverse (or beneficial) changes in the properties of structural metals brought about by irradiation generally do not appear large or significant for any one property. It is rather the combination of new and different values for the various properties that makes one hesitate to approve a given metal for reactor applications. It is believed that radiation effects in metals have the potential of making some metals unsuitable in the absence of irradiation. To determine whether this potential will be realized is extremely important and exceedingly costly. The answers are important to the builder, the operator, and the insurer of a nuclear reactor.

It has not been the intent of the authors to be overly pessimistic about the effects of radiation on metals. The desire has been to show that there are still many material problems remaining to be answered before the reactor designer can proceed with complete confidence in the reliability of many of our commonly used metals and alloys.

KAPL-677

Chipman D R and Warren B E
AN X-RAY METHOD FOR STUDYING RADIATION DAMAGE IN GRAPHITE,
Knolls Atomic Power Laboratory, Schenectady, N.Y., and Massachusetts Institute of Technology, Cambridge, Mass., Contract No. W-(31-109)-Eng-52 and AT-(30-3)-49, February 1, 1952, 28 pp. (3 refs).

Radiation damage in graphite produces in certain X-ray reflections a broadening of the diffraction peak, accompanied always by a shift of the peak position toward smaller angle. A treatment analogous to that used for cold work distortion in metals is applicable, and the analysis outlined by Warren and Averbach is presented for the case damaged graphite. Using several orders of the (002) reflection, the complex Fourier coefficients are obtained, and from these a function is synthesized giving the distribution of changes in distances perpendicular to the graphite layers. The present report is intended only to present a method for the X-ray diffraction study of damaged graphite and not to give reliable results on the nature of the damage.

KAPL-830

Coffin L F, Jr. and Wesley R P
AN APPARATUS FOR THE STUDY OF THE EFFECTS OF CYCLIC THERMAL STRESSES ON DUCTILE METALS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, October 27, 1952, 47 pp. (6 refs).

In cases in which very high rates of heat transfer exist, as in nuclear reactors, severe thermal stresses can be developed in structural metals. These stresses can be relieved by plastic flow and, consequently, are not regarded as serious when steady-state conditions prevail. Under the action of thermal oscillations, however, cyclic thermal stresses are developed. Depending on the frequency of thermal cycles and the severity of the thermal stress, fatigue failure can result. Because of its low thermal conductivity and high thermal expansion 18% chromium-8% nickel stainless steels are particularly prone to this effect.

An investigation of this problem has been under way for some time. The object has been twofold: (a) to obtain information so that a particular material may be assessed critically for its resistance to thermal stress fatigue damage under specified conditions, and (b) to investigate the fundamental aspects of the problem in order to learn more about the fatigue phenomenon.

The present report describes the test apparatus developed for this study. A report in preparation gives the test results to date and their interpretation. Essentially, the apparatus subjects a tubular test specimen of a structural material to a one-dimensional constraint. By subjecting the specimen to cyclic temperatures, an alternating uniaxial stress is developed which will produce a fatigue failure in the specimen after a sufficient number of stress cycles. The device has considerable flexibility in adjustment of temperatures of cycling and frequency of oscillation. A control system permits the cycle to continue automatically to failure of the specimen. Modification of the apparatus permits the strain cycling of test specimens at constant temperature.

The apparatus has the advantage of subjecting materials to a simple stress system which can be measured directly. It is possible to separate out elastic and inelastic strains and to study the effect of strain hardening with cycling. Effects of prestraining and stress concentrations can be investigated readily.

Attention has been given to temperature distribution in the specimen; all other possible stresses which may arise are found to be secondary in effect. Randomness in fracture location substantiates this.

KAPL-853

Coffin L F, Jr.
A STUDY OF THE EFFECTS OF CYCLIC THERMAL STRESSES ON A DUCTILE METAL,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52,
June 3, 1953, 129 pp. (54 refs).

The results of a study of cyclic strain and fatigue failure arising from cyclic thermal stresses are reported. By means of a test apparatus described in a companion report,* a cyclic temperature is imposed on a thin tubular test specimen subjected to complete longitudinal constraint. Hence, the cyclic strain is the independent variable.

The following studies are reported: (1) effect of thermal stress cycling on strain hardening and life-to-failure for a fixed mean temperature, (2) effect of degree and kind of previous cold work on strain hardening and cycles-to-failure, (3) effect of mean temperature on thermal stress cycling, (4) effect of period of cycle on cycles-to-failure, (5) effect of prior strain cycling on stress-strain characteristics, and (6) effect of stress concentrations on fatigue by cyclic thermal stresses.

The significance of factors such as hysteresis, Bauschinger effect, strain hardening, strain aging, and fatigue crack formation are discussed, and a mechanism is described to relate these factors. Evidence is presented to show that strain hardening is not an important factor in the problem. The concept of total plastic strain is discussed.

*KAPL-830, "An Apparatus for the Study of the Effects of Cyclic Thermal Stresses on Ductile Metals," L. F. Coffin, Jr., R. P. Wesley, October 27, 1952.

KAPL-1037

Tucker C W, Jr. and Sampson J B
INTERSTITIAL CONTENT OF RADIATION DAMAGED MATERIALS FROM PRECISION X-RAY LATTICE PARAMETER MEASUREMENTS.--I. PRINCIPLES OF THE MEASUREMENTS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52,
January 26, 1954, 22 pp. (22 refs).

An X-ray method for determining the interstitial content of irradiated metals is suggested and analyzed. This approach offers the following advantages:

1. The X-rays "see" mainly the interstitial atoms since their effect outweighs that of vacancies by a 5:1 ratio.
2. The interpretation is straightforward and may be made quantitative.
3. The method is sensitive, since 0.01 atomic per cent and perhaps less of the interstitial may be detected.

These conclusions are based upon a combination of theory and experiment. The theory is based upon an elasticity interpretation which predicts Vegard's law and several other experimentally confirmed X-ray effects. The possibilities of the method are confirmed by preliminary observations in this laboratory of X-ray detected lattice expansions of several neutron irradiated metals.

KAPL-1095

Bruch C A, McHugh W E and Hackenbury R W
EMBRITTLEMENT OF MOLYBDENUM BY NEUTRON RADIATION,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52,
March 1, 1954, 53 pp. (17 refs).

Commercially pure molybdenum specimens were irradiated in the MTR for an estimated exposure of 1.9 to 5.9 x 10^{20} thermal nvt. Prior to irradiation, the material was ductile in the tension test, whereas after irradiation it was brittle. The results of tension tests conducted at various temperatures revealed that the transition temperature for this material had been increased for -30°C to +70°C as a result of the radiation exposure. From metallographic studies it is concluded that the embrittlement is due to submicroscopic changes which raise the flow curve of the material. The results presented show that comercially pure molybdenum is an unsafe material for low-temperature (below 100°C) use in load-carrying reactor components.

KAPL-1158

Cashin W M and Tucker C W, Jr.
X-RAY DIFFRACTION EFFECTS TO BE EXPECTED FROM IRRADIATED URANIUM,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52,
August 13, 1954, 5 pp.

The expected X-ray effects in irradiated uranium are compared with effects in ionic, covalent, and metallic crystals. The unique changes due to fission product formation are discussed. Some criteria for the suitability of experimental techniques in the study of damage are presented.

KAPL-1242

Sowman H G and Lukesh J S
AN EXPLORATORY INVESTIGATION OF GLASSES EXPOSED TO INTENSE NEUTRON RADIATION,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52,
November 15, 1954, 14 pp.

Seven glass specimens of binary and ternary compositions were observed after exposure to a total thermal integrated flux of approximately 2 x 10^{20} nvt. All of the glass specimens retained their vitreous character, original surface texture, and gloss after irradiation. No visible mechanical damage was evident in any of the samples. All were discolored to some extent, and significant density and hardness changes occurred in some.

KAPL-1307

Lukesh J S
AN X-RAY STUDY OF THE EFFECTS OF INTENSE NEUTRON IRRADIATION ON THE STRUCTURE OF SOME GLASSES,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52,
March 29, 1955, 13 pp. (refs).

Detailed X-ray scattering curves have been obtained for four glasses subjected to intense neutron irradiation. No evidence indicating incipient devitrefication was observed.

KAPL-1366

Kunz F W
INFLUENCE OF NEUTRON BOMBARDMENT ON COLD-WORKED AND CARBURIZED IRON SINGLE CRYSTALS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, June 23, 1955, 29 pp. (17 refs).

Carburized and cold-worked single crystals of iron were irradiated at room temperature to a total integrated flux of 10^{18} nvt to determine the effect of neutron irradiation on the mechanical properties of iron crystals hardened by other means prior to irradiation. The results presented show that the effect of solute atom hardening plus irradiation hardening can be described as an additive process; in contrast, the hardening effect of irradiation decreases with increasing amounts of cold work. The data have been interpreted on the basis of defect agglomerates of vacancies and interstitial atoms produced during collision events.

KAPL-1371

Beard A P, et al.
PREPARATION OF NUCLEAR POISON AND CONTROL ALLOYS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, June 17, 1955, 31 pp. (10 refs).

Stainless steel base boron alloys with nominal compositions of 18 wt % chromium, 14 wt % nickel, and 0.4 to 3.2 wt % boron were successfully cast into ingots by vacuum induction melting. Alloy ingots containing up to 2.4 wt % boron were fabricated into 0.100-inch strip by forging and rolling at 1140° to 1175°C. An ingot containing 3.2 wt % boron could not be fabricated by the same procedure. Chemical analyses on as-cast ingots and rolled strip indicated very high boron recovery and good homogeneity. Brinell hardness numbers of the alloys were directly proportional, and measured densities were inversely proportional to boron content.

KAPL-1403

Valovage W D
EFFECTS OF IRRADIATION ON HOT-PRESSED BORON CARBIDE,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, November 15, 1955, 45 pp. (2 refs).

Hot-pressed boron carbide was irradiated in vacuo, in helium, and in sodium to determine the quantity of helium released and the physical stability of this material after burnups as high as 36% of the B-10 atoms. The quantity of helium released, in terms of the percentage of generated helium, was determined as a function of burnup and temperature.

It was found that extensive physical damage occurs, beginning with loss of hardness and cracking after very low burnup and increasing with burnup until complete granulation results after 36% burnup. At each level of burnup investigated, those specimens irradiated in sodium were damaged more extensively than specimens in vacuo or in helium.

KAPL-1416

Baldwin E E
EFFECTS OF TEMPERATURE AND RADIATION UPON THE TENSILE AND IMPACT PROPERTIES OF ASTM-A-302-B MANGANESE-MOLYBDENUM STEEL
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, October 1, 1955, 61 pp. (1 ref).

With the use of high-yield-strength low-alloy steels for nuclear reactor pressure vessels, it is important to know whether the operating conditions of temperature and radiation will affect the mechanical properties of these steels and the magnitude of such effects. Tensile and impact specimens of ASTM-A-302-51T Grade B manganese-molybdenum steel were fabricated, canned, charged into the Brookhaven reactor, and irradiated to an integrated fast neutron flux of 3.7×10^{18} nvt at 500° and 700°F. Comparison of tensile and impact test data on irradiated and unirradiated specimens showed that the separate and combined effects of temperature and radiation had only minor effects (less than 10%) upon the tensile and impact properties of the steel tested.

KAPL-1570

Merten U and Belouin D C
CORROSION BEHAVIOR OF ZIRCONIUM-BASE URANIUM ALLOYS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, June 15, 1956, 39 pp. (8 refs).

The corrosion behavior in high-temperature water of zirconium-base alloys containing 7 to 8 wt % of uranium has been studied. A marked dependence of behavior on prior heat treatment was observed. In the annealed condition the alloys lost weight at rates of the order of one milligram per square decimeter per hour of exposure to 360°C water. In the quenched condition the same alloys gained weight consistently, without any visible loss of oxide, for periods up to 4000 hr in length. The use of sponge zirconium or a Zircaloy in place of crystal bar zirconium in preparing the alloy had no noticeable effect on the corrosion resistance of the annealed material, but appeared to increase the corrosion rate observed after quenching.

KAPL-1874

Mehan R L and Baldwin E E
EFFECT OF NEUTRON RADIATION ON NOTCHED BEND AND TENSILE PROPERTIES OF ASTM A-201A CARBON STEEL,
General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, November 8, 1957, 37 pp. (9 refs).

Notched bend and tensile tests were conducted on ASTM A-201 Grade A carbon steel irradiated in the Materials Testing Reactor at temperatures of 300°F ± 100 to a maximum integrated fast flux of 4.3×10^{20} nvt. Mechanical properties changed drastically; the yield strength increased to a maximum of 195% above the pre-irradiation value. The transition temperature increased an unknown amount, probably in excess of 400°F. It was verified that recovery of radiation-induced damage follows an equation of the form $\tau = A e^{-Q/RT}$ that relates the time and temperature of recovery.

The results indicated that the KAPL-30 in-pile loop could be operated safely to an integrated fast flux of $\sim 4 \times 10^{20}$ nvt provided the loop received an annealing treatment of at least one hour at 600°F subsequent to each operating cycle.

KAPL-1877

Ahmann D H, et al.
A UO_2-BISMUTH SYSTEM AS A REACTOR FUEL,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, July 1, 1957, 21 pp. (3 refs).

Capsule experiments made with UO_2-bismuth slurries at 500° to 600°C indicate that titanium is the best additive to use to promote the wetting of UO_2 by bismuth. It was found in these capsule experiments that 10 to 12 wt % UO_2 could be uniformly dispersed in bismuth. Loop studies demonstrated that it is possible to pump at least an 8 wt % UO_2 in bismuth slurry in a loop with an electromagnetic pump at 450°C.

LAC-NR-5 (Vol. 3)-31

Morgan C E
EFFECT OF RADIATION ON THE CRITICAL SHEAR STRESS OF A METAL SINGLE CRYSTAL,
Convair, Div. of General Dynamics Corp., Fort Worth, Tex. Paper presented at the 3rd Semi-Annual Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 10 pp. (10 refs).

A mechanism is postulated to account for the radiation hardening of a metal single crystal. The mechanism is based on a lattice defect consisting of interlocking dislocation rings. According to this model, the critical shear stress of a metal single crystal varies as the cube root of the integrated fast neutron flux. This agrees well with the results of experiments by Blewitt, et al., on irradiated high-purity copper crystals.

LAC-NR-51 (Vol. 4)-49

Kulp B A and Reynolds D C
EFFECTS OF ELECTRON BOMBARDMENT ON CADMIUM SULFIDE WHISKERS,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corporation, Marietta, Georgia, 3 pp. (12 refs).

Edge emission normally found in large crystals of CdS is not found in CdS whiskers and platelets in the as-grown condition. Bombardment of these whiskers by 700 and 500 kev electrons has brought out this emission. The threshold for producing the effect is being determined.

LAC-NR-51 (Vol. 5)-63 FZM-1161

Bauerlein R R
THE PLATE SHEAR METHOD FOR DETERMINING RADIATION EFFECTS ON THE MODULUS OF RIGIDITY OF HONEYCOMB SANDWICH PANELS,
Convair, Div. of General Dynamics Corp., Fort Worth, Tex. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 6 pp.

A new testing method--the Plate Shear Method--has been developed for obtaining the modulus of rigidity in a mixed radiation field. The Plate Shear Method has proved to be more consistent and more reliable than the Beam Deflection Method. Furthermore, it is adaptable to testing during the irradiation process.

This paper describes the Plate Shear Method, its application, and the remotely controlled equipment required for its application. In particular, it discusses the advantages of the new method in yielding design data on honeycomb sandwich panels being tested for use in a nuclear-powered aircraft.

LRL-145

Steele R V and Wallace W P
THE EFFECT OF NEUTRON FLUX ON THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS,
California Research and Development Co., Livermore Research Laboratory, Livermore, Calif., May (1954), 20 pp.

Aluminum alloys 2SO, 2SH14, 52SO, 52SH34, 61SO, 61ST6, and A54S were irradiated at a maximum temperature of 150°F to a total neutron irradiation of 1.26×10^{21} n/sq cm in order to determine the effect of neutron irradiation on the mechanical properties. It was determined that the flow stress was increased markedly, particularly for the soft tempers, by the neutron exposure. The usual tensile strength was increased by the irradiations, whereas, the percentage of elongation was decreased, but not in every case.

For the same value of increase in flow stress (or the usual tensile strength), the ductility, as measured by the percentage of elongation, is markedly greater when this increase is accomplished by neutron exposure rather than by mechanical strain hardening.

For a given true stress of 0.05 true strain, the strain hardening exponent is greater for irradiated specimens than for control specimens. Also, for a given value of unstrained strength, the strain hardening exponent is greater for irradiated specimens than for control specimens.

MIT-1085

Klein J L and Nowak W B
EFFECT OF IRRADIATION ON THE X-RAY LINE SHAPE OF 2S ALUMINUM FROM A HANFORD WATER-COOLING TUBE,
Massachusetts Institute of Technology, Cambridge, Mass., Contract No. AT-(30-1)-981, December 7, 1955, 24 pp. (4 refs).

Measures of the internal distortions in cold-worked and irradiated 2S aluminum have been made by means of a Fourier analysis of X-ray line shapes. The (220) and the (311) reflections were recorded on a Norelco High-Angle Spectrometer. Changes in the resolution of the K_α doublet indicated that a fast neutron irradiation of about 4×10^{20} n/cm^2 produced further distortions in previously cold-worked 2S aluminum. The Fourier coefficients yield quantitative values for the rms distortions produced by cold work, and by cold work plus irradiation. Residual rms strains attributable to irradiation are of the same order of magnitude (0.1%) as those caused by cold work.

MIT-1107

Aronin L R
EFFECTS OF FAST NEUTRON IRRADIATION ON ORDER-DISORDER IN NICKEL-MANGANESE ALLOYS,

Massachusetts Institute of Technology, Cambridge, Mass., Contract No. AT(30-1)-981, April 28, 1953, 60 pp. (26 refs).

Effects of fast neutron irradiation in a Hanford reactor on order-disorder in a series of nickel-manganese alloys ranging from 16.5 to 31.9 atomic percent manganese have been studied by resistivity and magnetic induction measurements. Attainment of an "irradiated state" differing from either cold work or thermal disordering is suggested by comparison of exposure results on initially cold work disordered and initially thermally disordered alloys at the Ni Mn composition. In a region from 16.5 to approximately 22% manganese, properties of thermally disordered alloys are markedly affected by irradiation. These effects also appear to be superposed on the disordering produced by irradiation of initially ordered alloys. From theoretical exponential dependence on period of irradiation, fast neutron disordering of Ni_3Mn is determined by relating the Bragg and Williams order parameter quadratically with resistivity and linearly with magnetic induction. Under conditions of the irradiation it is estimated that each lattice site undergoes, on the average, one atomic replacement when the thermal component of integrated flux reaches 2×10^{20} n/cm^2. This leads to a figure of 5000 for the ratio of the number of atomic replacements to the number of primary collisions with neutrons of energy in excess of 0.5 Mev -- subject, however, to uncertainty arising from estimation of the fast flux.

MR-0159

Zaehringer Alfred J
IGNITION OF SOLIDS,
Missiles and Rockets, Vol. 5, No. 4., p. 43, January 25, 1959.

Ignition of solids is undergoing considerable research. Work in Zurich has shown that high intensity light can initiate detonations. At the University of Cambridge, electric fields have been used for ignition. On the other hand, neutrons, alpha particles, and other large fission fragments were not capable of producing ignition hot spots. At 10^4 roentgens, there is no great effect. To 10^7 roentgens only decomposition rates are changed. At Princeton University, shock waves have been used to ignite solid propellants (double base and composite). A helium shock wave of Mach 4 can ignite the solids. Aberdeen Proving Ground reports shock initiation of solids. University of Utah work outlines the transition from deflagration combustion to detonation when an inert solid medium interrupts deflagration.

NAA-SR-13

Gilmore F R, Malmstrom C R and Jarrett A A
TECHNIQUE OF RESISTIVITY MEASUREMENTS ON CYCLOTRON BOMBARDED GRAPHITE,
North American Aviation, Inc., Contract No. AT-(11-1)-Gen-8, April 4, 1949, 17 pp. (7 refs).

Graphite, exposed to proton, deuteron or alpha particle bombardment in the 60-inch cyclotron at Berkeley, undergoes large changes in electrical resistivity. The change is a function of the exposure and of the distance along the path of the particles in the graphite.

A previous report described a method for measuring these changes in resistivity and included some preliminary experimental results. The present work describes further refinements of both the experimental technique and the analytical procedures. The resistivity change in layers 0.001" thick in graphite can be measured to an accuracy of about 5% using these techniques.

NAA-SR-23

Parkins W E, Nuding J M and Eggen D T
RESULTS OF PULSE-ANNEALING MEASUREMENTS ON THE ELECTRIC RESISTIVITY OF IRRADIATED GRAPHITE,
North American Aviation, Inc., Los Angeles, Calif., Contract No. AT-(11-1)-Gen-8, October 17, 1949, 29 pp. (8 refs).

Improvements are described in the experimental technique of measuring electric resistivity changes in irradiated graphite by pulse-annealing. Results of annealing measurements up to about 2000°C are given for graphite subjected to short exposure on a cyclotron and to a wide range of exposures in a Hanford reactor. The dependence of the annealing measurements on the graphite temperature during irradiation and on the length of exposure are discussed.

NAA-SR-33

Bowen D
THE ELECTRICAL CONDUCTIVITY OF IRRADIATED GRAPHITE, PART I,
North American Aviation, Inc., Los Angeles, Calif., Contract No. AT-(11-1)-Gen-8, September 29, 1949, 13 pp. (3 refs).

A theory of the electrical conductivity of irradiated graphite has been developed which explains the saturation of resistivity as a function of exposure.

The saturation effect results from a competition between the increased number of carriers created by the atoms knocked from the lattice, and increased electron scattering caused by these displaced atoms and holes.

A comparison of the theory with existing measurements on resistivity is given.

NAA-SR-59

Bowen Dwain
THE THERMAL CONDUCTIVITY OF IRRADIATED GRAPHITE,
North American Aviation, Inc., Los Angeles, Calif., April 20, 1950, 21 pp. (8 refs).

A theory of the electronic thermal conductivity of irradiated graphite is developed.

It is found that for unirradiated graphite the Lorenz number (Wiedemann-Franz law for metals) times T^2 is a constant. The available experimental data fit this law reasonably well; hence, it may be concluded the major portion of the thermal conductivity of graphite is electronic.

This report is based on studies conducted for the Atomic Energy Commission under Contract AT-(11-1)-Gen-8.

NAA-SR-71

Dienes G J
A PROGRAM FOR THE STUDY OF RADIATION EFFECTS ON MECHANICAL PROPERTIES,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, June 7, 1950, 29 pp. (48 refs).

The main purpose of this report is to indicate the most promising avenues of approach in studying the effect of radiation on mechanical properties. First, a critical analysis of our fundamental knowledge of the mechanical properties of solids is presented and the main gaps in theoretical understanding are pointed out. Consequently, some mechanical properties are far more suitable than others for a fundamental study of radiation effects. A brief description of radiation effects is given. This is followed by a discussion of the mechanical properties most profitably studied from a fundamental standpoint and those which can only be treated empirically at the present time. A set of specific suggestions is given for an exploratory program.

NAA-SR-165

Green L
HIGH TEMPERATURE COMPRESSION TESTS ON GRAPHITE,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, January 7, 1952, 17 pp. (7 refs).

Experiments on the compression of graphite cylinders at temperatures up to about 2600°C are described. It is found that the short-time compressive strength increases with temperature in the range from room temperature to 2000°C in a manner paralleling the tensile strength behavior. Typical stress-strain curves are presented, but the limited degree of experimental control dictated by the available test equipment makes the results only semiquantitative in nature. The large, mutually opposing influences of temperature and strain rate are illustrated by photographs of typical failures.

NAA-SR-168

Duwez Pol and Johnson R D
THE EFFECT OF IRRADIATION ON DIFFUSION IN COPPER-GOLD AND COPPER-NICKEL POWDER COMPACTS,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, March 7, 1952, 31 pp.

Techniques are described for performing intermetallic diffusion experiments in the presence of both cyclotron and reactor irradiations. Diffusion specimens are in the form of powder compacts of definite particle size. The progress of diffusion is determined by X-ray diffraction measurements of the lattice parameter of one phase of the solid solution. Results are presented for experiments in the gold-copper and copper-nickel systems irradiated on the 60-inch University of California cyclotron and in a Hanford hot test hole. No significant effect of irradiation on the rate of intermetallic diffusion has been detected in the two systems studied, although both systems diffuse by substitutional methods. An interpretation of the results is presented on the basis of theory previously reported for intermetallic diffusion in powder compacts.

NAA-SR-211

McClelland J D
CHANGE IN MAGNETIC SUSCEPTIBILITY OF IRRADIATED GRAPHITE DURING PULSE ANNEALING,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, December 18, 1952, 11 pp. (5 refs).

Pulse annealing studies are presented of the magnetic susceptibility of AGOT-KC graphite with irradiations of 12.5, 48, 146, 460 and 1534 mwd/ct in the Hanford "B" test hole. The samples were pulsed stepwise in steps of approximately 100°C to a temperature of 2180°C where the samples showed complete recovery to their preirradiation value. The curves show two active annealing regions, the first between 100° and 500°C and the second between 1100° and 1500°C. The data are in good agreement with theory.

NAA-SR-262

Brinkman J A and Gilbert W S
EFFECTS OF FISSION FRAGMENTS ON RADIATION DAMAGED METALS,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, November 15, 1953, 34 pp. (5 refs).

Thorium metal and Au-3% Th alloy specimens were irradiated with both 9 Mev protons and 18 Mev deuterons. The deuteron irradiation was found to anneal some of the damage produced by the protons and to produce a different type of damage. These effects are interpreted as the result of fission fragments produced by the irradiation of thorium with deuterons. It is believed that the damage annealed by these fission fragments consists of interstitial-vacancy pairs, and the damage produced by the fission fragments consists primarily of dislocation loops.

NAA-SR-1198

Austerman Stanley B
ACTIVATION TEMPERATURES FOR ANNEALING OF NEUTRON-DAMAGED GRAPHITE AS DETERMINED BY ISOTHERMAL PULSE ANNEALING,
Nuclear Engineering and Manufacturing, North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, September 1, 1955, 52 pp. (17 refs).

As part of the program to understand the mechanisms of annealing behavior in irradiated graphite, specimens of 48 Mwd/ct pile-irradiated graphite were subjected to pulse-annealing, and simultaneous measurements were made of thermal and electrical resistivities and thermoelectric power. Activation temperatures, calculated for annealing at temperatures up to 1850°C showed a continual rise from about 18,000°K at the beginning of low temperature annealing to about 70,000°K at 1400°C annealing temperature. Analysis of the annealing rates in conjunction with the calculated activation temperatures shows that the annealing processes cannot be explained by simple chemical kinetics, but that a model of overlapping annealing states governed by increasingly higher activation temperatures as annealing progresses must be used. In the region of 1200°C the annealing behavior demonstrates a system involving at least two opposing processes.

NAA-SR-1367

Bowen D B
SOLID-STATE PHYSICS QUARTERLY PROGRESS REPORT, JANUARY-MARCH, 1955,
Nuclear Engineering and Manufacturing, North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, September 15, 1955. 25 pp. (14 refs).

This progress report covers work in solid-state physics performed by the above group during the period stated. Work during this quarter covered Graphite, Metals, and Cyclotron Operation and Development. The following is a list of problems covered.

I. Graphite
   A. Survey of Radiation Damage in Graphite
   B. Theoretical Rate of Defect Production in Graphite
   C. Post-Irradiation Measurements of Cyclotron and Neutron-Irradiated Graphite
   D. Stored Energy Release Experiments
   E. Low Temperature Thermal Conductivity of Potassium Chloride

II. Metals
   A. Electron Irradiation of Copper at -196°C
   B. Tensile Properties of Electron Irradiated Copper

III. Cyclotron Operation and Development
   A. Operation
   B. Impurity Atom Experiments

NAA-SR-1398

Hove John E
THERMAL CONDUCTIVITY OF GRAPHITE - THEORETICAL STUDY OF ELECTRON-PHOTON SCATTERING,
Nuclear Engineering and Manufacturing, North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, January 1, 1956, 43 pp. (13 refs).

A calculation has been made of the contribution to the thermal resistance in graphite of the scattering of the photons by the conduction electrons. This investigation was undertaken in order to determine whether the effects of neutron damage on the thermal conductivity could be explained by the change in the number of effective electrons caused by trapping of the electrons. The conclusion reached is that this cannot be done, principally because it is found that the thermal conductivity, due to this mechanism, should become more strongly dependent on temperature as electrons are removed from the conduction band, whereas it is observed that this temperature dependence is weakened. The important implication of this result is that the thermal conductivity is a sensitive probe for detecting the lattice defects introduced by neutron damage, since it is not complicated by electronic effects.

NAA-SR-1452

Bowen Dwain
SOLID-STATE PHYSICS QUARTERLY PROGRESS REPORT, APRIL-JUNE 1955,
Atomics International Div. of North American Aviation, Inc., Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, March 15, 1956, 35 pp. (21 refs).

This document covers the progress of Atomics International in the field of solid-state physics. The first portion is devoted to the radiation damage in graphite and presents data on a model analysis and the correlation of neutron flux with radiation damage. Further, work on low temperature annealing of graphite and stored energy in graphite is discussed.

Part 2 of the publication covers efforts in the field of metals as used for reactor construction. The metals investigated include thorium and nickel. The changes in X-ray lines, cold working effects, mechanical properties, and energy bands in thorium are discussed, as are the displacement energy of nickel and a new method of determining activation energies.

NAA-SR-1464

Hove John E
THEORY OF THE MAGNETIC SUSCEPTIBILITY OF GRAPHITE: THE VARIATION WITH TEMPERATURE, BROMINATION AND NEUTRON DAMAGE,
Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, March 15, 1956, 28 pp. (18 refs).

The magnetic susceptibility of graphite shows a very high diamagnetic value which is extremely anisotropic. Previous theoretical interpretations of this have utilized the two-dimensional approximation, wherein only a single basal plane of graphite is considered. Such a theory will explain the variation of the susceptibility with neutron damage or with the formation of bromine-graphite compounds, but only in a qualitative way. The quantitative results of the theory disagree rather badly with the experimental data, especially as regards the variation with temperature. In the present report, the three-dimensional graphite structure is utilized, adopting the electron energy band approximation of Wallace. In the latter work, two parameters appear (the so-called resonance integrals between nearest neighbors in a plane and nearest neighbors in adjacent planes) which are treated as disposable constants in the present paper and evaluated by fitting appropriate experimental data. In this way, the respective values for these resonance integrals are found to be 1.63 and 0.5 ev. Theoretical estimates used in previous work are 1.0 and 0.1 ev for these values, and it is seen that the difference in the magnitudes for the adjacent plane parameter is appreciable. This implies that the three-dimensional effects in graphite may have been seriously underestimated in some previous work. Using the experimentally determined parameters, this writer has found that the relative temperature dependence of both unirradiated and neutron-irradiated graphite can be satisfactorily predicted. Similarly, the relative variation of the susceptibility with bromination can be accounted for on a quantitative basis. However, the absolute magnitude of the susceptibility, as determined theoretically, is lower by a factor of 40 than the observed value. The reasons for this discrepancy are not yet well known.

For neutron damages less than about 100 Mwd/ct, it is found that the electron trapping rate varies from 1×10^{-4} to about 0.3×10^{-4} electrons/atom/Mwd/ct as the damage is increased. This agrees reasonably well with the trapping rate of 0.9×10^{-4} as estimated from the Hall coefficient variation in a previous work by Eatherly.

NARF-57-53T MR-N-163

Johnson R E and Sicilio F
RADIATION DAMAGE TO METAL BONDED AND SANDWICH PANELS - I,
Engineering Dept., Convair, Div. of General Dynamics Corp., Fort Worth, Tex., Contract No. AF33(600)-32054, November 26, 1957, 38 pp. (13 refs).

Samples of three types of panels were irradiated in air using the Ground Test Reactor in October 1955. The three types were lap shear panels, aluminum- and fiberglas-core honeycomb panels, and corrosion-resistant steel honeycomb panels. In addition, two groups of clad aluminum lap shear panels were irradiated while immersed in various fluids.

In the air-immersion irradiations, flux levels of 6×10^{14} $n_f vt$, 6×10^{13} $n_t vt$, and 5×10^{16} γ/cm^2 were attained. In the fluid-immersion irradiations, fluxes of 6×10^{14} $n_t vt$ and 5×10^{16} γ/cm^2 were attained.

After irradiation, engineering tests were made on both irradiated and control samples. Comparisons were made of the test results of the two groups to determine the effect of radiation on the materials.

Most of the panels were found to be resistant to radiation at the levels experienced. Only the following changes were noted:

1. Lap shear panels made with Plastilock 620-626 adhesive on magnesium to 2024-T3 clad aluminum showed a decrease in shear strength.
2. Fiberglas-core aluminum-skin honeycomb panels made with Hexcel 422-J adhesive exhibited a decrease in column creep and shear strength.
3. Corrosion-resistant steel sandwich panels decreased in face compression strength.

NARF-58-9T MR-N-192

Morgan C E
EFFECT OF NEUTRON IRRADIATION ON THE CRITICAL SHEAR STRESS OF A METAL SINGLE CRYSTAL,
Engineering Dept., Convair, Div. of General Dynamics Corp., Fort Worth, Texas, Contract No. AF33(600)-32054, March 20, 1958, 62 pp. (28 refs).

A mechanism is postulated to account for the change in the critical shear stress of a metal single crystal upon irradiation. This mechanism is based on a lattice defect consisting of interlocking dislocation rings. The dislocation rings are formed by plastic deformation of the matrix around thermal or displacement spikes in the metal, as suggested by Seitz. They remain in the lattice after irradiation to impede the movement of slip-dislocations. From this model, an expression for the critical shear stress varies as the cube root of the integrated neutron flux. The variation (after irradiation) of the critical shear stress with temperature is also discussed from the standpoint of this mechanism.

Other radiation-hardening mechanisms (viz., interaction of slip dislocations with interstitials and vacancies, formation of stacking faults or agglomerations of interstitials and vacancies and formation of jogs on dislocations) are discussed and the dislocation ring mechanism compared with them. The agglomerated point defect or stacking fault mechanism and the dislocation ring mechanism differ in that, while the former requires diffusion of interstitials or vacancies before the irradiated metal is hardened, the dislocation ring method predicts that metals will be hardened by radiation even at the lowest temperature without warning.

To test the theory, the critical shear stress of copper was calculated for neutron doses up to 2×10^{19} nvt. The calculated values agree quite well with available experimental data on irradiated high-purity copper crystals.

Extension of the theory of polycrystalline metals and alloys is also discussed.

NARF-58-48T MR-N-163-2

Bauerlein R R
RADIATION DAMAGE TO METAL-BONDED AND SANDWICH PANELS-II. EFFECTS OF RADIATION ON HEXCEL 91LD AND HEXCEL F-120 HONEYCOMB CORE REINFORCED WITH FIBERGLAS,
Convair, Fort Worth, Tex., Contract No. AF33(600)-32054, December 17, 1958, 14 pp. (2 refs).

In an experiment to investigate the effects of radiation on the compressive strength of honeycomb cores, samples of Hexcel 91LD and Hexcel F-120 honeycomb core, each reinforced with fiberglas, were irradiated with the Ground Test Reactor. Specimens were irradiated at ambient temperature at four different radiation levels with the maximum being a gamma dose of 9.3×10^9 ergs/gm (C) and an integrated fast-neutron flux of 1.2×10^{15} n/cm^2.

Within the statistical accuracy of the tests, the compressive strength of neither type of honeycomb core was found to be adversely affected by the irradiation.

NAVR-SYM-ACR-2 (4)

Smoluchowski R
SURVEY OF RADIATION EFFECTS,
Carnegie Institute of Technology, Pittsburgh, Pa. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 4 pp. (6 refs).

Most of our knowledge of the influence of nuclear irradiation on solids is based on study of these phenomena in metals rather than in other materials. This is so in spite of the fact that the commonly measured effect is the change of the metallic electrical resistivity which is often quite difficult to interpret. For this reason in this brief summary of various radiation effects, an attempt will be made to stress the differences and similarities between effects occurring in metals and in nonmetals. This is approached from the theoretical interaction standpoint with little reference to experimental proof.

NAVR-SYM-ACR-2 (5)

Pearlstein E and Ingham H
CHANGES OF ELECTRICAL CONDUCTIVITY OF ALKALI HALIDES UNDER IRRADIATION WITH HIGH-ENERGY PROTONS AND GAMMA-RAYS,
Carnegie Institute of Technology, Pittsburgh, Pa. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 6 pp. (2 refs).

The experiments on proton irradiation of alkali halides were started with the hope that some basic information could be obtained about the number of vacancies and interstitials produced by high-energy ionizing particles and also about the behavior of these imperfections. The results do not as yet point definitely to any simple interpretation, and a number of questions are raised, some of which can be answered by additional experiments.

NAVR-SYM-ACR-2 (6)

Pearlstein E and Ingham H
ENERGY DEPENDENCE OF RADIATION EFFECTS,
Carnegie Institute of Technology, Pittsburgh, Pa. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 1 p. (1 ref).

The original object of this experiment was to test the validity on the 1/E dependence of radiation effects upon energy of the incident charged particle, as predicted in the formulas of Seitz. The measure of radiation effect was the change in electrical resistivity of tungsten at room temperature.

NAVR-SYM-ACR-2(8)

Delbecq C J, et al.
SOME EFFECTS OF RADIATION ON ALKALI HALIDES, ALKALI NITRATES, AND DIAMOND,
Argonne National Laboratory, Lemont, Ill. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 9 pp. (18 refs).

Various crystals have been exposed to X-rays, gamma-rays, fast electrons, deuterons, neutrons, and ultraviolet light, and some of the effects of the impinging radiation have been observed. The changes in the optical absorption of the crystals have been studied in greatest detail; however, changes in chemical, electrical, and para-magnetic properties and birefringence have also been measured. Although the alkali halides, because of the relatively simple structure and availability, have been studied in greatest extent, some attention has been given to alkali nitrates and diamond.

NAVR-SYM-ACR-2(10)

Kreidl N J
RADIATION EFFECTS ON GLASS,
Bausch & Lomb Optical Co., Rochester, N.Y. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 2 pp.

This is a two-page abstract which discusses the effects of radiation on silicate and phosphate glasses.

NAVR-SYM-ACR-2(13)

Wittels M C and Sherrill F A
PILE BOMBARDMENT EFFECTS IN SOME REFRACTORY CRYSTALS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 3 pp. (7 refs).

A group of natural crystals having comparatively high melting temperatures were bombarded with fast neutrons at a temperature of approximately 100°C. Preliminary X-ray examination of these materials following irradiation indicates that many of these crystals undergo large disordering effects as a result of knock-on displacements. Most of the crystals examined are in the class of low density insulators with oxygen atoms forming the structurally dominant component of the lattice. In addition, a considerable degree of covalent binding is a common characteristic of these crystals.

NAVR-SYM-ACR-2(16)

Sturm W J
THE EFFECTS OF PILE NEUTRON IRRADIATION ON THE STRUCTURE OF LITHIUM FLUORIDE,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper given at Conference on Effects of Radiation on Dielectric Materials held at Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 5 pp.

The object of the work discussed here has been to determine the type of lattice defect induced in lithium fluoride by pile neutron bombardment. The parameter chosen for the observation was the lattice parameter, and the measurements made were those of changes in this parameter as a function of pile bombardment and of time and temperature of thermal anneal. Lithium fluoride was chosen for the work partly because it is an easily available single crystal having simple and well-determined structure.

NBS-5272

Swerdlow M and Geller, R F
SURVEY OF RADIATION-RESISTANT GLASS,
National Bureau of Standards, Washington, D.C., May 1, 1957, 48 pp.

This report presents a survey of radiation-resistant glass. The topics discussed are effects of radiation; sources and kinds of high energy radiation; types of interaction with matter; radiological quantities, units, and symbols; and nuclear radiation environment associated with System 125A.

The information presented was obtained from a selected bibliography and can be summarized as follows:

At dosages of approximately 10^6 roentgens of Co^{60} gamma radiation, many optical glasses become darkly colored and practically opaque to visible radiation. At dosages over 10^{10} r the discoloration reaches a saturation point. The brown coloration is not stable but fades with time, temperature and exposure to ultraviolet or visible radiation. The color induced in a crown glass exposed to 10^6 r could be completely bleached in a few hours by heating at 400°C. The flint glasses color more readily than crown glasses, but fade more quickly. As the gamma radiation dosage is increased beyond the saturation point, the glasses can be ruptured or cracked. Because optical glass becomes useless as an image-forming material long before mechanical damage occurs, gamma radiation dosages below 10^{10} r are considered the present practical limit for the use of optical instruments in such a radiation flux.

Some irradiated glasses, especially phosphate glasses containing cobalt, will exhibit fluorescence with ultraviolet excitation. Other irradiated glasses containing traces of thorium, cerium, silver, chromium, cobalt, and manganese will exhibit the phenomenon of thermoluminescence, that is, visible radiations of definite wavelengths will be emitted when the glass is heated after irradiation. The liberation of heat from a nuclear reactor will be an important consideration in regions close to the reactor.

Capture of thermal neutrons by glasses containing potassium, calcium, zinc, arsenic, cerium, and especially cobalt, can result in making the glass hazardously radioactive for some time after nuclear irradiation.

NESC-57-108

Proctor Joseph H
APPLICABILITY OF CLAD STEELS TO HEAVY WATER PIPING,
Lukens Steel Co., Coatesville, Pa. Published by the American Society of Mechanical Engineers, 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 7 pp. (2 refs).

This report is an evaluation of the applicability of clad steel in heavy water piping. Clad steels made up of the following alloys: stainless steel, nickel, monel, inconel, and

copper, bonded to carbon steel backing were evaluated.

Tests were made to determine that clad steel could withstand service conditions of heat and pressure encountered in reactor operation.

Fabrication considerations were investigated and welding techniques proposed.

NRL-3717

Furlong L R
A SURVEY OF THE THEORETICAL ASPECTS OF THE LUMINESCENCE OF INORGANIC CRYSTALLINE SOLIDS,
Naval Research Laboratory, Washington, D.C., July 28, 1950, 36 pp. (44 refs).

A general mode of attack rather than a time-tested formulation of luminescence theory is presented--because the latter does not exist. The various phases of luminescence have been studied independently of the other phases, using individual luminescent systems. Consequently, the "theory" of luminescence actually consists of a number of theories, each of which has been constructed to describe the properties of a particular luminescent system. The theories presented, therefore, apply to individual systems, but they are indicative of the way in which luminescence problems are handled in general and they do, at least, lead to some understanding of the processes involved. No attempt at unification of these theories has been made because more concrete knowledge (for example, concerning the constitution of electron traps) will have to be obtained before a consistent, overall theory of luminescence can be constructed.

NYO-1114

Wikle K G and Beaver W W
ELEVATED TEMPERATURE PROPERTIES OF BERYLLIUM,
Brush Beryllium Co., Cleveland, Ohio, Contract No. AT-(30-1)-541, July 15, 1952, 22 pp. (3 refs).

The elevated temperature tensile properties of hot-pressed QMV beryllium have been studied from 250° to 950°C. Also those of warm-pressed, hot-extruded beryllium have been investigated from 250° to 600°C.

Data obtained to date indicate that the ultimate tensile strength of the hot-pressed material decreases slowly from room temperature to 600°C and rapidly from there on. Ductility increases above room temperature to a peak at about 450°C then rapidly decreases to a low value. Material that is more ductile at room temperature is also more ductile at the 450°C peak.

Special equipment developed for tensile-testing beryllium up to 950°C is illustrated and described.

NYO-3131

Smoluchowski R, et al.
RADIATION EFFECTS IN SOLIDS--PROGRESS REPORT FOR JANUARY 1 TO JULY 1, 1954,
Carnegie Institute of Technology, Pittsburgh, Pa., Contract No. AT-(30-1)-1193,
September 24, 1954, 5 pp.

Large effects of proton and of gamma irradiation on electrical conductivity of alkali halides were observed and studied during continuous heating. A tentative interpretation is suggested. Measurements of mechanical properties are still hampered by lack of reproducibility. Study of surface effects by means of multiple beam interferometry has been completed. Optical absorption measurements on alkali halides and on sapphire are continuing and also on small-angle X-ray scattering in diamond. The dependence of resistivity increase in tungsten upon the energy of the incident protons is being studied in order to verify the proposed role of "star" formation in radiation effects.

NYO-3454

Ricker C W, Schaf H F and Werme J V
DEVELOPMENT OF RADIATION PYROMETRY TECHNIQUES FOR MEASUREMENT OF TEMPERATURE DURING THE ROLLING OF URANIUM,
Minneapolis-Honeywell Regulator Co., Philadelphia, Pa., Contract No. AT-(30-1)-1316, May 1, 1953, 74 pp.

This report covers work performed on Contract No. AT-(30-1)-1316 between the Brown Instruments Division of the Minneapolis-Honeywell Regulator Company and the New York Operations Office of the Atomic Energy Commission.

The emittance of salt-coated uranium (a eutectic mixture of lithium and potassium carbonates) was found to be about 0.86 between the temperatures of 900° and 1200°F. The emittance of uranium oxide ($U_3 O_8$) was found to be about 0.82; the emittance of the salt mixture was 0.9; and the emissivity of uranium metal between 200° and 600°F was 0.15. A holder and housing for the Brown Miniature Radiamatic Radiation Pyrometer was developed which was flexible and could be used to advantage measuring the temperature of uranium ingots and bars during the rolling operation. A number of these units were fabricated for the Feed Materials Center at Fernald, Ohio. A calibration panel was designed and built which permitted easy calibration of the Radiamatic assemblies. This panel contained a blackbody furnace as a radiation reference source.

NYO-3777

Kreidl N J
IRRADIATION DAMAGE TO GLASS,
Bausch & Lomb Optical Co., Rochester, N. Y., Contract No. AT-(30-1)-1312, March 12, 1953, 14 pp. (7 refs).

The irradiation damage to glass is being studied in three phases. First, a fundamental investigation is being made of the change of physical properties with irradiation in simple glasses containing controlled simple components; e. g., cerium. Second, the relation between protection, quality, intrinsic color, and composition of glasses required in specific designs is investigated in detail with the aim of developing glasses for particular irradiation levels. Third, instruments incorporating these glasses are being designed for use where resistance to radiation is required.

The five glasses selected for development have been "protected" against exposure to 10^6 r gamma radiation. Results are given of the change in absorption with exposure of "protected" and "nonprotected" glass. The development of two of these glasses is completed. The remaining three require some improvement in quality or adjustment of optical properties.

The fundamental study is guided by effects and methods known in the case of irradiation of crystals-the measurement of absorption and fading, as affected by irradiation and heat treatment. In a silicate-base glass, the ultraviolet absorption bands of cerium are concealed by the characteristic absorption of the glass. By using a phosphate-base glass, the cerium absorption bands in the ultraviolet and their change with irradiation were clearly observed. The oxidation level of cerium in silicate- and phosphate-base glasses was controlled.

NYO-3780

Kreidl N J and Hensler J R
IRRADIATION DAMAGE TO GLASS,
Bausch & Lomb Optical Co., Rochester, N.Y., Contract No. AT-(30-1)-1312, November 1, 1954, 91 pp.

Silicate and phosphate glasses exposed to gamma radiation develop a visible absorption similar to the F-band developed in alkali-halide crystals. In optical glasses this decrease in transmission prevents their use under exposure conditions. Cerium in the glass prevents this coloration. Five conventional optical glasses containing cerium were developed, maintaining the optical constants, high quality, and good color while "protecting" them against exposure to 10^6 roentgens.

Optics and instruments utilizing these glasses were developed and tested, particularly a stereo relay system, a remote viewing microscope.

The function of cerium in preventing coloration of the glass was studied in detail in an ultraviolet transmitting phosphate-base glass, where it was established that the visible absorption caused by radiation was well resolved with respect to the ultraviolet absorption produced by radiation. The absorption in the ultraviolet region produced by cerium in this glass could be observed as affected by oxidation-reduction, concentration of cerium, and radiation. With oxidation-reduction and radiation, the absorption change was in the region of the cerium absorption but not coinciding with the cerium absorption maxima. It was concluded that the presence of enough cerium to permit interaction of freed electrons, normally inclined to form F-type centers, with vacancies near the specific electronic system of the cerium ion or with the resonating association of cerium ions in the vicinity of each other, produces a center of high energy absorption in preference to the one associated with the vacancies of the cerium-free glass.

On this basis, transition ions of similar electronic structure were introduced regardless of whether the ions cause color in the unirradiated glasses thus making them impractical for "protection." It was found that iron, manganese, cobalt, nickel, vanadium, and copper do suppress the formation of the visible absorption band formed in the base glass by radiation while forming more or less prominent bands in other spectral ranges. The colorless iron phosphate glass remained colorless under radiation and could be considered "protected." Conversely, with cobalt, the new band which reached into the visible, was relatively intense and stable suggesting its use to indicate radiation dose. Certain elements of this group, which in glass are particularly stable in their higher valency, were ineffective in that the base glass irradiation characteristics were not suppressed. Among these were Ti^{4+}, W^{6+}, and Sn^{4+}. However, by use of chemical reducing conditions in the glass melt, some Ti^{3+} was formed and the glass was "protected." This mechanism may allow some generalizations.

NYO-3784

Kreidl N J and Hensler J R
IRRADIATION DAMAGE TO GLASS
Bausch & Lomb Optical Co., Rochester, N.Y., Contract No. AT-(30-1)-1312, March 1, 1956, 25 pp.

Visible coloration typically formed by radiation in phosphate base glass was accompanied by electron spin resonance. When this particular coloration was prevented by the addition of small amounts of transition elements to the glass, the spin resonance was also prevented, even though a new coloration appeared upon irradiation. Spectroscopic splitting factors indicated that paramagnetic centers which also gave rise to the visible absorption typical of the irradiated phosphate glass were associated with the P^{31} nucleus.

The effect of radiation on GeO_2 glass showed some similarity to effects with SiO_2 in that pure GeO_2 was rather insensitive. However, the addition of small amounts of alkali to GeO_2 decreased its sensitivity not only to irradiation but also to chemical attack by water. The explanation may lie in the polymorphism of GeO_2.

The investigation of the effect of transition elements present in a glass, on the sensitivity and stability of colors formed by radiation, showed that a borosilicate glass containing cobalt had both high sensitivity and high stability making it useful in dosimetry. Saturation could be controlled to some extent by controlling transition ion concentrations.

NYO-3786

Kreidl N J and Hensler R
IRRADIATION DAMAGE TO GLASS,
Bausch & Lomb Optical Co., Rochester, N.Y., Contract No. AT-(30-1)-1312, October (1957), 18 pp.

Investigation of irradiation of very pure SiO_2 powder, the basic glass making raw material, doped with controlled impurities in very small amounts allowed synthesis of known color centers and discovery of new centers. Thermoluminescence measurements were fruitful in the investigation of mechanisms of repair of radiation damage. Interaction of centers responsible for ultraviolet and visible bands was indicated by the partial quenching of luminescence during thermal bleaching of samples showing visible coloration.

NYO-7379

Smoluchowski R, et al.
RADIATION EFFECTS IN SOLIDS,
Progress Report for July 1954-July 1955, Carnegie Institute of Technology, Pittsburgh, Pa., Contract No. AT-(30-1)-1193, September 9, 1955, 8 pp.

Nonmetals -- Electrical conductivity, density, elastic constants, stored energy, and optical absorption have been measured on irradiated and nonirradiated KC1 and NaC1 crystals. Among others the results indicate that there are several thousand vacancies produced per incident high energy proton. The mechanism of annealing is being investigated in detail.

Metals -- Experimental results on the dependence of irradiation effects in tungsten upon the energy of the incident protons agree with theoretical calculations based on the

previously proposed star formation model. Neutron irradiation of alpha brass can be accounted for in terms of the formation of short-range order.

NYO-7623

Bray P J
RADIATION DAMAGE STUDIES IN SOLIDS; NUCLEAR RESONANCE ABSORPTION TECHNIQUE,
Brown University, Providence 12, R.I., Contract No. AT(30-1)-1880, September 1, 1956, 17 pp. (refs).

A complete nuclear magnetic resonance spectrometer has been placed in operation. Many necessary and useful modifications of the commercial design are incorporated. The resultant instrument is exceptionally good for the observation of resonances which can be studied with high r.f. levels. Subsidiary equipment (magnet, cryostat, etc.) is also in operation.

NMR studies of damaged metals are being started in copper, copper-beryllium alloys and beryllium. Investigation of radiation damage in molecular solids will begin shortly.

Three appended abstracts summarize the publishable work to date on boron carbide, glasses containing boron, and ionic crystals containing boron or aluminum.

NYO-7624

Bray P J
RADIATION DAMAGE STUDIES IN SOLIDS; NUCLEAR RESONANCE ABSORPTION TECHNIQUE,
Depart. of Physics, Brown University, Providence 12, R.I., Contract No. AT-(30-1)-1880, September 1, 1957, 22 pp. (15 refs).

Radiation damage effects have been observed and measured in several alkali halides (NaI, KI, LI, and KBr) which have received reactor irradiation. The data have been used to determine the defect density in the irradiated crystals and the mean free path between displacement collisions. The results are in substantial agreement with the calculations of Seitz and Koehler.

Preirradiation studies of boron carbide have shown that the central "carbon" position in the "three-carbon chain" of this structure is often occupied by a boron atom.

Preirradiation studies of boron oxide-alkali oxide glasses have uniquely determined the boron-oxygen configuration and bonding behavior as a function of the glass composition. The results offer an explanation of the thermal expansion and volume per oxygen dependence on the oxygen content of the glass.

The bonding electron distributions in several metal borides and boron nitride have been determined from the effect of B^{11} electrical quadrupole coupling constant on the nuclear magnetic resonance.

Studies are in progress on radiation damage effects in metals, corundum, and molecular compounds.

ONRL-50-58

Sherby Oleg D
AACHEN CONFERENCE ON METAL PLASTICITY AND IRRADIATION DAMAGE IN METALS,
Office of Naval Research, Branch Office, London, England, June 19, 1958, 19 pp.

A conference on the plasticity of metals and irradiation damage in metals was held at the Technical University, Aachen, Germany, March 3-7, 1958. It was organized primarily to bring together young German metal physicists active in the subject matter of the conference. The emphasis was on informality and on extensive discussion of each paper. Forty attended the conference, of whom thirty read invited papers. This report is a summary of the various papers presented.

ORNL-681

English James L
THE CORROSION OF 356 ALUMINUM IN SIMULATED COOLING WATER FOR THE PROPOSED MATERIALS TESTING REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26,
July 20, 1950, 107 pp.

A report is presented on the corrosion of 356 T-7 aluminum in simulated cooling water for the proposed Materials Testing Reactor. Stagnant and dynamic corrosion tests were conducted in demineralized water containing small amounts of hydrogen peroxide at a pH range of 5.5 to 6.5 and a temperature of 85°C. Corrosion behavior of the uncoupled alloy was investigated as well as its galvanic corrosion behavior with 2S aluminum, 43 aluminum, extruded beryllium, and 347 stainless steel. Sodium chromate and sodium dichromate were tested as possible corrosion inhibitors.

The corrosion characteristics of 356 aluminum are greatly influenced by oxygen concentration pH and contact with dissimilar metals. Heat treatment of the alloy affected the corrosion resistance slightly; cast aluminum showed a slightly superior corrosion resistance to the heat-treated alloy. Corrosion attack on the alloy at 90°C was of similar magnitude as attack at 30°C; and maximum corrosion attack occurred at 50°C. Stagnant vs dynamic test results indicated that pitting intensity was reduced under dynamic conditions, but the general corrosion rate was increased. Corrosion attack generally increased as the hydrogen peroxide concentration increased from 0.0005 M to 0.005 M. Galvanic corrosion attack on the alloy was most severe when coupled to 347 stainless steel. Sodium chromate in concentration of 10 ppm was effective for reducing corrosion attack. A general observation of all test results indicated that an incubation period of 500 to 700 hours was required for the formation of the protective hydrated aluminum oxide film.

The average over-all stagnant corrosion rate for 356 aluminum in deaerated water, 0.0005 M and 0.005 M hydrogen peroxide solutions for 1008 hours, was 0.007 mil/month; the average dynamic corrosion rate for similar conditions was 0.067 mil/month. In deaerated water, the presence of 10 ppm of sodium chromate resulted in negligible corrosion rates; in waters containing 0.0005 M and 0.005 M hydrogen peroxide concentrations, the average corrosion rate was 0.020 mil/month with almost complete elimination of pitting attack.

Galvanic corrosion of 356 aluminum in contact with 2S aluminum, 43 aluminum, extruded beryllium, and 347 stainless steel in deaerated water, 0.0005 M hydrogen peroxide, and 0.005 M hydrogen peroxide solutions, averaged 0.013, 0.010, 0.025, and 0.355 mil/month

for 1008 hours exposure, respectively. With 5-10 ppm. of sodium chromate in the test solutions these corrosion rates were reduced to 0.007 mil/month in contact with 2S aluminum, 0.001 mil/month in contact with extruded beryllium, and 0.007 mil/month in contact with 347 stainless steel. The maximum pit depth encountered on stagnant 356 aluminum test specimens was 16.4 mils in 1008 hours; for dynamic test conditions, the maximum pit depth encountered was 8.0 mils for the safe time.

ORNL-975

Kernohan Robert H and McGammon Grace M
FADING CHARACTERISTICS OF GAMMA-INDUCED COLORATION IN HIGH DENSITY GLASS,
Fairchild Engine and Airplane Corp., and Oak Ridge National Laboratory, Contract No. W-(7405)-Eng-26, March 20, 1957, 14 pp.

Specimens of a lead silicate glass manufactured by the Penberthy Instrument Company were measured for transmission characteristics. The specimens were given varying dosages from a 300 curie cobalt-60 gamma source. Transmission characteristics were measured as a function of time following irradiation. The gamma-induced coloration faded and this fading could be accelerated by illuminating the specimens with an ordinary light bulb. All specimens nearly recovered their original transmission characteristics.

ORNL-2149

Thurber W C, Milko J A and Beaver R J
BORON-ALUMINUM AND BORON-URANIUM-ALUMINUM ALLOYS FOR REACTOR APPLICATION,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, October 18, 1957, 23 pp. (7 refs).

Additions of small quantities of the burnable poison (boron) in aluminum reactor fuel elements offer the possibility of reducing undesirable neutron-flux perturbations, especially those caused by fuel burnup. This report describes techniques for induction melting of boron-aluminum and boron-uranium-aluminum alloys for producing materials with maximum homogeneity. Of the several boron additions investigated, a nominal 12 wt % B-Ni master alloy was the most satisfactory for preparing boron-uranium-aluminum castings, while both 1.5 to 5 wt % B-Al and 12 wt % B-Ni master alloys were suitable for preparing boron-aluminum castings. Data are presented which indicated that boron improves the strength of aluminum. The corrosion resistance of a nominal 0.1 wt % B-0.8 wt % Ni-Al alloy is comparable with Type 1100 aluminum in distilled and aerated water at both 60° and 100°C. Without the nickel, this alloy appears to be marginal in these environments.

ORNL-2413

SOLID STATE DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING AUGUST 31, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, November 26, 1957, 126 pp. (refs).

This report summarizes the progress made in the Solid-State Division of the ORNL for the period ending 8/31/57. The subject matter covered includes the following: (1) low-temperature bombardment of metals; (2) the temperature dependence of the mechanical properties of metals; (3) Youngs modulus and internal friction studies; (4) small angle X-ray scattering studies of fast-neutron irradiation effects in an aluminum-silver precipitate alloy; (5) effect of neutron irradiation on copper base alloys; (6) the precipitation-hardening reaction in nickel-beryllium; (7) electron microscope studies; (8) chemical properties of metal surfaces; (9) low-temperature irradiation of n-type germanium; (10) minority-carrier lifetime studies in germanium; (11) mobility changes in irradiated n-type germanium; (12) annealing studies of irradiated germanium; (13) optical absorption in germanium; (14) activation energies and total energies of localized states in semiconductors; (15) magnetic properties of arsenic-doped silicon; (16) magnetic susceptibility of molybdenum; (17) instrumentation for susceptibility studies; (18) magnetic defects in covalent and ionic crystal systems; (19) super-heterodyne electron-spin resonance spectrometer; (20) optical absorption studies of irradiated solids; (21) X-ray diffraction studies; (22) low-temperature thermal conductivity of potassium chloride crystals, including the effects of strain and particle irradiation; (23) low-temperature thermal conductivity of nonmetals; (24) low-temperature thermal conductivity in neutron-irradiated vitreous silica; (25) proposed reactor bombardments at 4° Kelvin; (26) gamma-source facilities; (27) automatic liquid-gas level control; (28) HRP radiation metallurgy; (29) radiation stability of ceramic materials; (30) Infra-red spectra of plastics and elastomers after irradiation; (31) effects of high-energy radiation on polymers; (32) analysis of gases evolved by irradiation of polymers; (33) effects of radiation on engineering properties of polymeric materials; (34) high-frequency electrical properties of some irradiated plastic materials; (35) attempt at the separation of neutrons and gamma-ray irradiation effects by means of a hydrogenous absorber; (36) an investigation of the properties of two uranium-bearing zeolites; (37) forced-cooled ceramic-fuel experiments; (38) high-temperature ceramic fuels; (39) radiation effects in thermocouple insulation; (40) chemical effects of nuclear reactions; (41) absorption of fission gases by activated charcoal; (42) investigation of sulfur contamination of a dry box of neoprene rubber; (43) neutron flux monitoring in high-temperature in-pile experiments; (44) ORR experimental facility; (45) fission reactions as threshold detectors; (46) hot lab studies.

PR-0358-1

Magnuson G D, Palmer W and Koehler J S
ISOTHERMAL ANNEALING BELOW 60°K OF DEUTERON IRRADIATED NOBLE METALS,
Physics Review, Vol. 109, No. 6, pp. 1990-2002, March (1958), (29 refs).

Foils of 99.999% pure copper, 99.999% pure silver, and a copper alloy containing 3.78 atomic percent nickel were irradiated near liquid helium temperature with 10.7 Mev deuterons. Annealing up to 60°K was performed in a series of isothermal steps. During each anneal the decrease of the radiation-induced resistivity increment with time was observed. Resistivity distribution curves, obtained by assuming that recovery processes with a continuum of activation energies are present, show several small peaks followed by a large peak. The maxima occur at 0.048, 0.080, 0.091 and 0.113 ev in copper and at 0.045, 0.058, and 0.079 ev in silver. The frequency factors for both metals were found to lie between 7.2×10^{10} and 3.9×10^{12} sec^{-1}. Alloying served to broaden the energy distribution of the recovery processes. Changes in the Debye characteristic temperature of $-(15 \pm 1)$°K and $-(10 \pm 1)$°K were also observed in copper and silver, respectively. Annealing of these changes was about 80% complete at 50°K. The dominant mechanism in the low-temperture recovery is believed to be the annihilation of Frenkel pairs, with the interstitials as the mobile defects. A trapping model

is proposed to explain why all the resistivity increment does not anneal out once interstitials begin to move.

PR-0458-1

Gross Bernhard
THERMOVOLTAIC EFFECT IN GAMMA-IRRADIATED BOROSILICATE GLASS,
Physical Review, Vol. 110, No. 2, pp.337-338, April 4, 1958, (4 refs).

Borosilicate glass was irradiated with a high dose of gamma rays from a Co^{60} source. After irradiation the glass was heated while a temperature gradient was maintained between its surfaces. During the heating an external current was observed. The direction of the current in the dielectric corresponded to a transport of negative charge to the electrode with the higher temperature.

PR-0458-2

Corbett J W and Walker R M
DISCRETE RECOVERY SPECTRUM BELOW 65°K IN IRRADIATED COPPER,
Physical Review, Vol. 110, No. 3, pp.767-768, May 1, 1958, (5 refs).

This short article reports an experiment on electron-irradiated copper which demonstrates directly, independent of analysis, that at least four regions of recovery exist in the temperature range 20° to 80°K.

PSP-0055-1

Levy M and Varley J H O
RADIATION-INDUCED COLOUR CENTRES IN FUSED QUARTZ,
Physical Society Proceedings, Vol. 68B, pp. 223-233, (1955), (18 refs).

Samples of fused quartz ('Vitreosil') have been irradiated by pile, gamma or X-rays and three absorption bands are produced with maxima at 2.3 ev, 4.1 ev and approximately 5.6 ev. It is suggested that the 2.3 ev band is due to sodium borate impurities in the glass.

All three bands can be bleached either optically or thermally or, more rapidly, by a combination of both processes. An empirical law describing the thermal bleaching rate of the 2.3 ev band over a large range of n is $dn/dt = -Ae^{bn}$ where n is number of colour centres per cm^3 at time t; A, b are constants.

Bleaching of the 2.3 ev and 4.1 ev bands can also be brought about by large doses of pile irradiation. This is attributed to vacancies caused by atomic displacements combining with electron traps to produce new centres. These latter are assumed to give an absorption outside the range of observation in these experiments, viz. 6.2 ev to 1.2 ev.

REIC-5 AD-157170

Allen B C, et al.
THE EFFECT OF NUCLEAR RADIATION ON STRUCTURAL METALS,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. AF33(616)-5171, May 31, 1958, 22 pp. (62 refs).

This report presents the state of the art on the effects of nuclear radiation on structural metals from 1943 through 1957.

The general effects of various types of radiation on metals are discussed and the damage mechanisms are outlined. Following this is a topical discussion of the effects of fast neutrons on the physical and electrical properties and corrosion resistance of metals. Tabular data are presented on these effects.

Experimental evidence to date indicates that structural metals are quite resistant to nuclear radiation when compared to such things as organic compounds or electronic components. Fast neutrons in integrated flux levels above 10^{19} nvt represent the only reactor radiation that can significantly affect the properties of structural nonfissionable metals.

An appendix is included which gives tabular data on effects of radiation on properties of metals and alloys.

REIC-TM-9

Riley W C, et al.
THE EFFECT OF NUCLEAR RADIATION ON GLASS,
The Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio, November 30, 1958, 24 pp. (130 refs).

The purpose of this technical memorandum is to present available information on radiation effects in glass and to recommend areas that require further investigation. The topics discussed are physical-property changes, optical systems, glass tubes, dosimeter glass, and a table summarizing radiation effects in glass.

REPF-105

Krueger Helmut
A SHORT STUDY OF IRRADIATION EFFECTS ON VARIOUS LEAD TITANATE ZIRCONATE COMPOSITIONS,
Clevite Research Center, August 16, 1956, 3 pp.

A preliminary irradiation of some lead titanate zirconate (PZT) and barium titanate disks has been done. Four samples each of seven different formulations of PZT were exposed to gamma irradiation. The results are briefly as follows:

(1) All capacitances dropped from 3 to 10%.
(2) All dissipations dropped.
(3) All resonant frequencies rose, seldom as much as 1%.
(4) Planar couplings of the three and five valent additions rose slightly. All others dropped slightly.
(5) With one exception, all mechanical Q's rose, one as much as 100%.
(6) As a rule, the greater total irradiation produced the greater change in the measured properties of the disks.
(7) Many of the changes are comparable to aging in magnitude and direction for the time difference involved. One month passed between initial premeasurements and postirradiation measurements.

REPF-109

Brusch C A and McHugh W E
RADIATION DAMAGE STUDIES OF SEVEN NON-FISSIONABLE METALS,
Knolls Atomic Power Laboratory, Schenectady, N.Y. Paper presented at Nuclear Engineering and Science Conference, March 17-21, 1958, Chicago, Ill., 69 pp.

Seven metals were irradiated under a variety of irradiation exposure conditions in three types of nuclear reactors. Measurements were made of both the exposure conditions and the resulting changes in properties. All of the metals experienced the same general effects, including increases in strength, hardness, and electrical resistance and decreases in ductility. It is doubtful that the range of neutron exposures covered was adequate to achieve saturation of the irradiation effects. Based on the experimental observations a qualitative picture of the radiation-damage process is suggested. If this proves to be correct, it may be possible to accelerate the evaluation of radiation damage to metals. Several general and empirical relationships are suggested which describe maximum observed changes in several properties.

REPF-110

Greene Charles H
THE RELEASE OF STRAIN IN PRINCE RUPERT'S DROP OF GAMMA IRRADIATION,
Alfred University, N.Y. Paper presented at Nuclear Engineering and Science Conference, March 12-21, 1958, Chicago, Ill., 6 pp.

Prince Rupert's drops made from two kinds of glass were subjected doses of cobalt-60 gamma radiation ranging up to 3.45×10^7 r. A slight amount of release of strain was observed after the maximum irradiation in drops made of soft lead glass, Corning brand 0120. The brown color developed in the strained drops of the lead glass was more intense than that in control samples which had been annealed. These effects were much less marked in drops made from a hard borosilicate glass, Pyrex brand 7740 which was also less colored than was the lead glass by the same amount of irradiation.

SCEL-M-1715

Koerbel C J
A RADIATION-SENSITIVE ALKALI-BARIUM GLASS FOR POSSIBLE USE AS A DOSIMETER,
Signal Corps Engineering Laboratories, Evans Signal Laboratory, Belmar, N.J., November 22, 1955, 21 pp.

Although a satisfactory glass for dosimetry has not been developed, this report describes the testing procedures and the nature of the failure of the glass to provide reproducible results, resist fading on exposure to ultraviolet, white light, tungsten light and infrared.

SCL-F-195

Saint-James D
A NEW ATTEMPT TO EXPLAIN THE PHENOMENA OF COLOR CENTERS,
A translation from Le Journal de Physique et Le Radium, Vol. 17, pp. 907-908, October (1956).

The interpretation of experiments with coloration of alkaline halides by means of irradiation presents numerous difficulties. Two types of models have been proposed in order to

explain the experimental results of the bands "V". F. Seitz suggests for those centers the models deduced from those utilized for the absorption bands "F". J. H. O. Varley, on the other hand, advances the idea of interpretation which is based on the creation of atoms in an interstitial position, entailed by a process of multiple ionization. The author discusses the new attempt to explain the phenomena of color centers.

SCTM-300-58(16)

Adolphson Donald R
ELEVATED TEMPERATURE PROPERTIES OF 2014-T6 ALUMINUM ALLOY,
Technical Memorandum, Sandia Corporation, Albuquerque, N. Mex., Contract No. AT-(29-1)-789, September 16, 1958, 22 pp. (6 refs).

This technical memorandum is a compilation of available elevated temperature data for 2014-T6 aluminum alloy. Included are mechanical and thermal data. Besides the variable of temperature, the effects of time at temperature, rate of loading, and rate of heating are included.

TID-5280(Suppl. 1)-5

Wilson J C, et al.
TENSION TESTING OF RADIOACTIVE SPECIMENS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, held in Washington, D.C., September 29 and 30, 1955, 18 pp. (4 refs).

This paper constitutes a summary of experience, at Oak Ridge National Laboratory, in carrying out tension tests on numerous metals and with a wide variety of sizes and shapes of test specimens. Starting with a consideration of the types of testing machines, grips, and extensometers available, the criteria for choice of each component are discussed.

It will be shown that the testing operations can be conveniently carried out in a hot cell with a single window, with floor dimensions of three by five feet, and a single master slave manipulator.

TID-5280(Suppl. 1)-7

Ferguson K R
WINDOWS FOR REMOTE VIEWING,
Remote Control Engineering Div., Argonne National Laboratory, Lemont, Ill. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, held in Washington, D.C., September 29 and 30, 1955, 22 pp. (8 refs).

The use of dense transparent materials as a radiation protective shield through which radio-active substances can be viewed is described. The properties of suitable commercial materials are tabulated. A digest of information including the effects of high intensity radiation, engineering considerations necessary to the design of a window, and pertinent details of construction are included.

TID-5280(Suppl. 1)-8

Ferguson K R
THE PERFORMANCE OF RADIATION PROTECTED MICROSCOPE OBJECTIVES,
Argonne National Laboratory, Lemont, Ill. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, held in Washington, D.C., September 29 and 30, 1955, 12 pp. (2 refs).

The coloration of microscope objectives exposed to beta and gamma radiation is discussed. The period of use of special objectives prepared from radiation protected glasses is compared to that for standard lenses. Test results are given for beta exposure up to 10^6 r and gamma exposures up to 10^6 r. Results of irradiation tests on lens cements are included.

TID-7565(Pt.1)-1 X-24978

Woodruff E M
DIMENSIONAL CHANGES ON IRRADIATED GRAPHITE,
Hanford Atomic Products Operation, Richland, Wash. Paper presented at the US/UK Graphite Conference held at St. Gibs Court, London, England, December 16-18, 1957, 11 pp. (9 refs).

Studies of the irradiation stability of graphites have been made in support of the design and operation of Hanford reactors. Portions of these studies pertaining to dimensional changes in irradiated graphite are discussed. Two types of reactor-grade graphite irradiated at low and high temperatures provide data demonstrating the effects of fabrication and irradiation variables. Studies of experimental graphites demonstrate the possibility of tailoring irradiation stability during fabrication.

Mechanisms for length changes in graphite resulting from irradiation at low and high temperatures and the results of annealing property changes are discussed.

TID-8004

Patterson Louise D
GAMMA RADIOGRAPHY OF METAL CASTINGS AT SANDIA LABORATORY,
Technical Information Division, Sandia Corporation, January (1956), 4 pp.

Consideration is given to the advantages of a relatively portable, inexpensive cobalt-60 gamma source for high-penetration radiography of materials. In general, such gamma sources are not capable of the resolution or short exposure times of the high-energy, more expensive X-ray machines or betatrons; however, there exist many applications in industrial radiography where such factors are not of prime consideration. A high degree of safety and convenience is obtained with the equipment described here.

WAL-MRL-53

Antal J J and Goland A N
A STUDY OF REACOTR-IRRADIATED -Al_2O_3,
Materials Research Laboratory, Ordnance Materials Research Office, Watertown, Mass., September (1958), 23 pp.

Studies are presented here on reactor-irradiated alpha-aluminum oxide single crystals. These are primarily a continuation of the use of long-wavelength neutron transmission

for determining the concentration and types of defects produced in solids by high-energy particle irradiation. The material exhibited crystallographic stability to fast neutron irradiation at temperatures < 40°C, and the results indicate a total number of defects approximately 40 times less than that predicted by current theories. Correlation with microscopic density changes is good. Examination of the wavelength dependence of the neutron scattering indicated that the damage may be partly Al-O vacancy pairs at room temperature. Annealing of the material produced no decrease in the concentration of defects from 400° to 1250°C, and nonuniform changes in neutron scattering and visually observable optical coloring beyond 1250°C. Annealing at a temperature of 1800°C did not remove the coloring, although the density returned to its preirradiation value.

WA-OMRO-13A-B5

Arutunian G and Renius O
THE EFFECT OF X-RADIATION ON THE OPTICAL PROPERTIES OF QUARTZ CRYSTALS,
Detroit Arsenal. Presented at Conference on Effects of Nuclear Radiations on Materials, October 1 and 2, 1957, Watertown Arsenal, Watertown 72, Mass., 15 pp. (2 refs).

The Detroit Arsenal has conducted a study to determine the effects of X-radiation upon the optical properties of natural quartz crystals. The quartz, upon exposure to ionizing radiation, changes transmission properties in the ultraviolet, visible, and infrared portions of the spectrum.

Samples of natural quartz crystals were exposed to X-radiation ranging from 50 kev to 15 Mev. The transmission properties of the quartz crystals were then evaluated in the wavelength range 0.2 to 15 microns. The transmission properties of the crystals were related to the radiation dose received for each source. Indices of refraction of the quartz were also measured before and after irradiation of the crystals.

The transmission properties of the crystals were re-evaluated after removing the effects of X-ray irradiation by heating the specimens at a temperature between 300° and 500°C for a period of two hours to determine the recovery effect of the crystals.

32

WA-OMRO-13A-B6

Mapes J E and Dreyfus R W
GAMMA-RAY INDUCED COLORING OF POTASSIUM AZIDE,
Picatinny Arsenal. Presented at Conference on Effects of Nuclear Radiations on Materials, October 1 and 2, 1957, Watertown Arsenal, Watertown 72, Mass., 13 pp. (5 refs).

The coloring of single crystals of potassium azide (KN_3) by gamma rays has been determined by optical transmission measurements in the visible and ultraviolet. After each exposure, the spectrum was measured immediately after removing the sample from the Co^{60} source and at intervals thereafter. The observed spectrum can be resolved into individual absorption bands. Each additional exposure increases the intensity of the induced color bands, but part of the increase decays with time. One group of bands decays slowly while another decays very rapidly. The application of color center data to the measurement of radiation damage is discussed.

WAPD-25

Cook L A, Castleman L S and Johnson W E
PRELIMINARY REPORT ON THE ELECTRICAL RESISTIVITY OF ZIRCONIUM,

Westinghouse Electric Corp., Atomic Power Div., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December 20, 1950, 19 pp. (4 refs).

Preliminary data have been obtained concerning the effects of temperature, cold work, irradiation and alloying additions of uranium upon the electrical resistivity of zirconium.

The resistivity vs temperature curve for zirconium has a relatively constant slope from -186° to 200°C; above 200°C, the slope of the curve decreases smoothly, and the resistivity approaches a maximum value in the vicinity of the $\alpha \rightleftharpoons \beta$ transition temperature (about 860°C) dropping abruptly thereafter to a minimum between 875° and 950°C. Above 950°C, the resistivity rises gradually and again with constant slope.

Cold work introduced by swaging operations has no effect upon the slope of the resistivity vs temperature curve at room temperature; however, the magnitude of the resistivity is increased by 4 to 6% after an 84% reduction in area. Also, the preferred orientation resulting from an 84% reduction in area followed by an anneal above the recrystallization temperature increases the resistivity by about 2%.

Irradiation of one sample of zirconium indicates that the resistivity of zirconium increases by about 3% after a six months' exposure in neutron fluxes characteristic of those found in a Hanford process hole.

WAPD-77

Bleiberg M L, Ely R L, Jr. and Witzig W F
CORRELATION OF ZIRCONIUM ELECTRICAL RESISTIVITY WITH FAST FLUX,
Westinghouse Electric Corp., Atomic Power Div., Pittsburgh, Pa., Contract No. AT-(11)-Gen-14, May 20, 1953, 21 pp. (6 refs).

The integrated fast flux distribution in the L-41 hole of the Materials Testing Reactor was determined for neutrons with energies between 2 and 7 Mev by using a fast flux monitor, S^{32} (n, p) P^{32}. It was possible to correlate these values of integrated fast-flux with changes in electrical resistivity of crystal bar zirconium and a 2.5% tin-crystal bar zirconium alloy.

WAPD-79

Witzig W F
WAPD-1 EXPERIMENTS IN THE MATERIALS TESTING REACTOR - I. GAMMA HEATING
WAPD-1-1,
Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, March (1953), 30 pp. (refs).

An experiment has been performed to measure the gamma heating effect in aluminum in the L-42 location within the active lattice of the Materials Testing Reactor. At full power a maximum value of 12.5 watts/gm was obtained at the reactor centerline. This value was approximately proportional to reactor power level at steady-state conditions. The value of gamma heat was found to be dependent upon vertical position in the reactor.

NUCLEAR FACILITIES AND ASSOCIATED TOPICS

A-0058

Swop H Gladys
THE ARGONNE HIGH LEVEL GAMMA IRRADIATION FACILITY--DESCRIPTION AND OPERATING PROCEDURES,
Argonne National Laboratory, Lemont, Ill. Paper presented in Atomproxis, Vol. 4, pp. 249-254 (1958).

The facility is a canal in which spent fuel rods from the Materials Testing Reactor are contained in specially constructed racks, the latter being at the bottom of the canal. The canal is 28 feet long, 14 feet wide, and 24 feet deep. The water level varies from 16 to 20 feet. The water is used as coolant and shield for the spent fuel rods. The water is demineralized and is continuously recirculated through a mixed bed ion-exchange unit at the rate of 800 gal/hr. The average temperature of the water is 76°F. There are three under-water irradiation racks in the gamma canal. In the main rack there are 12 fuel rods arranged in the form of a honeycomb, so that there are six sample ports surrounded by four fuel rods and six sample ports adjacent to two fuel rods. Where four fuel rods surround a sample, the sample being 4 in. in diameter, intensities as high as 3.5×10^6 rads/hr have been obtained.

A/Conf. 15/P/424

Averbach T, et al.
PRELIMINARY DESIGN OF A HIGH FLUX, EPITHERMAL RESEARCH REACTOR FOR THE BROOKHAVEN NATIONAL LABORATORY,
Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 16 pp. (3 refs).

The Brookhaven High Flux Intermediate Reactor (HIFI) provides an intensive neutron source at low power, facilitating effective and economical neutron research. A preliminary design concept based on calculations for this reactor type produces fluxes, both thermal and epithermal, in the range of 10^{14} to 10^{15} n/cm^2-sec., and is therefore competitive with the best existing reactor sources.

The new features of the reactor are its low power level of 10 to 20 Mw, and the spatial separation of peak epithermal and thermal fluxes in the core and reflector respectively.

A/Conf. 15/P/2364

McReynolds A W, Stein J M and Taylor T B
PULSED SOLID HOMOGENEOUS REACTORS FOR RESEARCH,
Paper presented at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy, June (1958), 18 pp. (5 refs).

The development of nuclear reactors has so far been directed exclusively toward reactors designed to operate at approximately steady power level. This paper considers the need for the properties of a second, complementary type - pulsed reactor, designed to operate in very short but very intense flashes. A graphite-uranium solid homogeneous reactor system, referred to here as a FLASH reactor, is described with respect to its design and physical properties.

AECD-3059 LADC-887

AN ENRICHED HOMOGENEOUS NUCLEAR REACTOR,
Los Alamos Scientific Laboratory, Los Alamos, N.M., January 25, 1951, 21 pp. (8 refs).

A decision was reached in August 1943 to build at Los Alamos a small homogeneous reactor that would use an aqueous uranyl salt solution enriched in U^{235}. This reactor became known as the "water boiler" and went critical in May 1944 with 565 g of U^{235}. This design is referred to as LOPO (lower-power water boiler).

This report also discusses a higher-power water boiler (HYPO) reactor. This design is discussed with respect to construction details (sphere assembly; reflector, thermal column, and radiation shield; control, shim, and safety rods; detectors and indicators; safety devices; and automatic pilot), operation (approach to critical; rod calibration; temperature effect; loss of nitrate and water; and controls and operational procedure), and performance (flux and power, and steadiness of operation).

Photographs, diagrams, and curves are included.

AECD-3063

Baker C P, et al.
WATER BOILER,
Los Alamos Scientific Laboratory, Los Alamos, N.M., September 4, 1944, 32 pp.

The structural features of the uranyl sulfate water boiler in use at Site Y are given in detail with a full account of the safety features. Results of the corrosion tests on stainless steel of which the sphere was made are presented, and the fabrication of the BeO tamper surrounding the sphere is described. The structure and function of the control rod and the safety rod, with their related mechanical systems, are explained, and an account is given of the temperature-controlling system.

The activity of the boiler was measured as the mass of active material approached criticality; the results are discussed in detail. The control rod was calibrated, and the effect of temperature change was noted. Measurements were also made on the super-critical period. Substituting graphite for BeO as tamper material increased the critical amount; the insertion of tuballoy* slugs did not improve the effectiveness of graphite tamper greatly.

*"Tuballoy" is used in this report to designate processed uranium with composition essentially the same as that of naturally occurring uranium.

AECD-3065

Bentzen F L, et al.
HIGH-POWER WATER BOILER,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Contract No. W-7405-Eng-36, September 19, 1945, 59 pp.

A detailed description of the design and construction of a 5.5-kw water boiler at Site Y is given. A 14% enriched uranyl nitrate solution in water is used as the reactor and moderator. The 13.5 liters of solution, containing 870 g of U^{235}, is held in a 1-ft dia stainless-steel sphere. The tamper consists of a BeO core surrounded by graphite. A thermal column is connected to one side of the tamper. The operation and performance of the boiler are described.

AECD-3163 WAPD-24

Schultz M A
AUTOMATIC CONTROL OF POWER REACTORS,
Westinghouse Atomic Power Division, Pittsburgh 30, Pa., Contract No. AT-(11-1)-Gen-14, November 6, 1950, 40 pp. (5 refs).

The use of automatic controls for power producing reactors is discussed with reference to start-up, operating, and shut-down problems. The transfer function of a reactor is obtained theoretically and the requirements of a servo system design discussed. Automatic control systems are presented for subcritical operation as well as for power range work. The use of the control system in prevention of enforced shut-downs is also indicated.

AECD-3435 ORNL-1105 (Rev)

Breazeale William M
A LOW COST EXPERIMENTAL NEUTRON CHAIN REACTOR - PART I,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April 15, 1952, 59 pp.

This report describes a low cost neutron chain reactor which was originally written in the Spring of 1951 for declassification purposes. Also included is a description of the reactor and controls and appendices discussing health physics aspects, abnormal behavior, and corrosion problems.

Appendix I -- Burnett T H J, "Health Physics Instruments for the Low Cost Reactor Installation."

Appendix II -- Clairborne H C and Poppendiek H C, "Transient Thermal Behavior of Low Cost Reactor When Prompt Critical."

Appendix III -- Drawings are included which describe the main features of the reactor and control circuits.

Appendix IV -- Olsen Arnold R, "Corrosion Studies on Aluminum Clad Reactor Fuel Element.

AECD-3656

McMurry H L
PERTURBATION THEORY AND APPLICATIONS,

Phillips Petroleum Company, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, June 11, 1952, 19 pp.

Perturbation methods for calculating changes in reactivity due to small changes in reactor composition or structure are developed. The equations for the reactivity changes are valid for nonuniform as well as uniform changes in the reactor. They form a convenient basis for interpreting some of the operational characteristics of the MTR.

AECD-3666

Garabedian H L
CONTROL ROD THEORY FOR A CYLINDRICAL REACTOR,
Westinghouse Atomic Power Division, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, August 9, 1950, 87 pp.

The work reported in this paper was carried out specifically for the purpose of making calculations associated with the control rod system for a cylindrical reactor. It is considered to be a combination and extension of the best results heretofore available in the American and Canadian literature on systems of rings of control rods in a cylindrical reactor. It gives a critical equation in the form of a determinental critical equation for two rings of rods and a central rod and special cases of such a system, formulas for flux distributions, a discussion of rings of rods in a reflected reactor, a discussion of extensions to higher orders of approximations, and the foundation for further papers on the subject of both analytical and computational character.

AECD-3667

Garabedian H L
THEORY OF HOMOGENEOUS CONTROL OF A CYLINDRICAL REACTOR,
Westinghouse Electric Corporation, Pittsburgh 30, Pa., Contract No. AT-(11-1)-Gen-14, September 20, 1950, 79 pp.

This paper is concerned specifically with the possibility, from a theoretical point of view, of controlling a cylindrical reactor with the aid of a large number of tubes of small diameter, containing mercury, which are symmetrically and uniformly distributed about the axis of the reactor. Techniques are developed which are indispensable to design studies of a reactor with a system of homogeneous control of the type described. The exposition on perturbation methods contained in this paper is applicable to a wide variety of reactor problems.

Two appendices are included:

Appendix I -- Derivation of the Two-Group Two-Region Perturbation Formula.

Appendix II -- Derivation of the One-Group Two-Region Perturbation Formula.

AECD-3668

Dietrich J R
EXPERIMENT INVESTIGATION OF THE SELF-LIMITATION OF POWER DURING REACTIVITY TRANSIENTS IN A SUBCOOLED WATER-MODERATED REACTOR,
Borax-I Experiments, Argonne National Laboratory, Lemont, Ill., Contract No. W-31-109-Eng-38 (1954), 84 pp.

During the early Summer of 1954 a series of experiments was made on the Borax-I reactor to investigate the ability of the reactor, when operated in the subcooled condition, to protect itself against the results of sudden, artificially induced increases in reactivity. Inasmuch as this set of experiments completed the program for the Borax-I reactor, the final runaway experiment was intentionally made under conditions which led to destruction of the reactor. In the final experiment a control rod worth 4% k_{eff} was ejected from the reactor core, inducing an exponential power increase of period 2.6 milliseconds. The results of this final experiment when combined with those obtained in the preceding milder tests indicate the behavior of the reactor over a wide range of conditions of excess reactivity.

The maximum power attained during the final experiment was determined to be between 13×10^9 and 20×10^9 watts, and the total energy liberation was approximately 135 megawatt-seconds. This energy release resulted in melting of most of the fuel plates and failure of the reactor tank. Fuel plate fragments were scattered for a distance of 200 to 300 feet from the reactor, but no widespread dangerous dispersal was observed.

The nuclear energy release during the final experiment was not far different from that which would be expected by extrapolation of the results of previous milder experiments. The thermal conditions induced by the energy release, however, are out of the range of previous experience, and it is therefore difficult to determine whether the ultimate destructive effects are consistent with the hypothesis of a simple steam explosion.

AECD-3669 MMPP-75-2

Luckow William K, Mesler Russell B and Widdoes Lawrence C
THE NUCLEAR RESEARCH REACTOR AT THE UNIVERSITY OF MICHIGAN-AN EVALUATION OF THE HAZARDS OF OPERATION AND PROVISIONS FOR LIMITING THESE HAZARDS,
University of Michigan, Ann Arbor, Michigan, April 22, 1954, 28 pp.

An evaluation of the hazards of operation and the provisions for limiting these hazards in the nuclear research reactor at the University of Michigan are discussed.

It is pointed out that the maximum credible accident to this reactor is believed to be slow dissolution of the fuel elements with the subsequent release of fission products to the pool water. An estimate is given of the radiation dose to an observer outside the reactor building during the first hour following the start of the maximum credible accident. Automatic monitors will be employed to set off area alarms during the early stages of such an accident.

AECD-3681

Bright G O
NEUTRON FLUX DISTRIBUTIONS IN THE MATERIALS TESTING REACTOR. - PART III. FUEL BURNOUT IN THE 3 X 9 LOADING,
Atomic Energy Div., Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July 27, 1954, 48 pp. (4 refs).

The distribution of fuel burnout in the Materials Testing Reactor after the first operating cycle has been computed. The work involves the use of flux distribution functions which were obtained experimentally during the acceptance testing period of the reactor. A process of numerical integration is used which yields results compatible with the

accuracy of the experimental data. The results are shown as a set of curves in which each fuel element and fuel-bearing shim-safety rod is represented.

Two appendices are included:

Appendix I -- Derivation of K, the Ratio of the Volume Integral of the Clean, Cold Reactor Flux Distribution Function to the Volume Integral of the Depleted Reactor Flux Distribution Function, and F, the Maximum Burnout at any Point.

Appendix II -- 27 Curves Representing the Average Fuel Burnout in Each Fuel Element and Each Fuel Shim-Rod for Cycle No. 1.

AECD-3682

Leyse C F
FACILITIES FOR IRRADIATIONS WITHIN THE MTR REACTOR TANK,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, June 5, 1953, 72 pp. (11 refs).

Since the issue of ORNL-963 "Materials Testing Reactor Project Handbook," there has been considerable progress in providing additional facilities for irradiations within the reactor tank of the MTR. This report provides information regarding both these additional experimental facilities and associated experimental facilities and reactor components.

The facilities discussed in sections of this report are as follows:

a. Reactor Tank Experimental Access Holes
b. Reactor Lattice Facilities
c. Beryllium Reflector Facilities
d. Hydraulic Rabbits
e. Pneumatic Rabbits

AECD-3691

Huffman J R
MTR TECHNICAL BRANCH QUARTERLY REPORT FOR FIRST QUARTER - 1955,
Atomic Energy Div., Phillips Petroleum Co., Idaho Falls, Idaho, Contract No.
AT-(10-1)-205, October 5, 1955, 38 pp. (25 refs).

Earlier difficulty was encountered of MTR fuel assemblies bulging under hydraulic pressure differentials. This appears to be solved successfully by using 0.065 in. outside fuel plates, 0.1875 in. side plates and lower end boxes of proper dimensions. Use was made of the Card Programmed Calculator (CPC) available at Bartlesville, Okla., to handle the growing number of machine calculations on critical mass, crystal reflectivities, decay-production chains, and cross sections.

New cross-section data have been collected on the crystal and time-of-flight spectrometers, but they have not been reduced to reportable form.

A potentiometric titration method of determining ceric ion concentration in the chemical dosimeter for measuring gamma irradiation is under development.

Preliminary work has shown that counting of delayed neutrons from irradiated samples of U^{235} is a feasible method for "nucleonic" assaying.

AECD-3707

Huffman J R
MTR TECHNICAL BRANCH QUARTERLY REPORT FOR FOURTH QUARTER - 1954, Atomic Energy Div., Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, March 31, 1955, 39 pp.

The fission breaks which have occurred in the MTR, first reported last quarter, have been traced to the bulging outward of the lower ends of the outside concave fuel plates of the fuel assemblies. It was found by hydraulic tests in the MTR and pressure tests on assemblies, both at the MTR and ORNL, that a pressure differential outward of greater than 5 psi will cause this bulging on 0.050 in. thick plates with 0.110 in. side plates.

A summary of the cross-section work for the year is given. Total cross sections on the crystal spectrometer have been reported on zirconium, hafnium, Np-237, Li-7, sodium, potassium, and rubidium.

Activation cross sections of Pa-233 have been refined. The program on the determination of activation cross sections by second order captures has produced results for the cross sections of Y-90, Pr-142, Ta-182, and Tb-160.

The Reactivity Measurement Facility has been undergoing mechanical and operational tests. Approach to criticality is planned during the first quarter of 1955.

AECD-3715

Leyse C F
IMPROVEMENTS IN MTR FUEL ASSEMBLIES AND OPERATING PROCEDURES, Atomic Energy Div., Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, February 1, 1954, 13 pp.

The changes in fuel assemblies, shim rods, core geometry, and reactor cycle that have been made since the MTR was placed in operation have been summarized. These changes have reduced the cost of fabricating fuel for the reactor from an initial value of $51.8/MWD to about $14.5/MWD at present. Some ways in which further improvements might be realized are summarized briefly.

AECD-3732

Paxton H C, Mallary E C and Horvath L S
OPERATING REGULATIONS FOR THE PAJARITO REMOTE CONTROL LABORATORIES, Los Alamos Scientific Laboratory, Los Alamos, N.M., Contract No. W-7405-Eng-36, January 18, 1956, 11 pp.

This document presents rules that govern the conduct of experiments with fissionable materials in Group W-2 of the Los Alamos Scientific Laboratory. It supersedes LAMS-456(1) and includes modifications suggested by experience accumulated over a five year period. The principal changes are intended to increase flexibility without compromising safety.

Because of the potential danger of fissionable materials, the most important concern of the regulations is the control of personnel hazard. Other significant purposes are to protect valuable fissionable materials and to minimize loss of operating potentiality of the group.

AECD-3770

Link L E and Guzik R F
ADDENDUM TO REACTOR BUILDING REPORT,
Materials Testing Reactor Project, Design Report No. 26A, Argonne National Laboratory, Lemont, Ill., November 17, 1949, 4 pp.

Changes, corrections and additions to the original report are included in this addendum. These are brought about by further development of the design by Blaw-Knox, ANL, and ORNL. The changes are listed in accordance with the main headings, pages and paragraphs to which they apply.

AECD-3771

Guzik R F and Link L E
REACTOR BUILDING WING,
Materials Testing Reactor Project, Design Report No. 27, Argonne National Laboratory, Lemont, Ill., October 12, 1949, 16 pp.

A reactor building wing is required to provide the laboratories, offices, and operational facilities necessary for the initial phase of the Materials Testing Reactor Project.

This report covers proposed design, recommendations, detailed disclosure of problem, design data, and detailed disclosure of design proposal. Four appendices are included.

AECD-3772

Link L E and Guzik R F
ADDENDUM TO REACTOR BUILDING WING REPORT,
Materials Testing Reactor Project, Design Report No. 27A, Argonne National Laboratory, Lemont, Ill., November 25, 1949, 2 pp.

Changes, corrections and additions to the original report are included in this addendum. These are brought about by further development of the design by Blaw-Knox, ANL, and ORNL. The changes in the original writings are listed below in accordance with the main headings, pages and paragraphs to which they apply.

AECD-3774

Guzik R F and Link L E
REACTOR BUILDING,
Materials Testing Reactor Project, Design Report No. 26, Argonne National Laboratory, Lemont, Ill., October 10, 1949, 23 pp.

This report is related to the reactor building associated with the Materials Testing Reactor Project at Argonne National Laboratory. The report covers proposed design, recommendations, detailed disclosure of problem, design data, and detailed disclosure of design proposal. Building structure is discussed and four appendices are included.

AECD-3998

Browder F N
SUMMARY OF SURFACE DECONTAMINATION EXPERIENCE AT OAK RIDGE NATIONAL LABORATORY,
November 1943 through July 1948, Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, (1948), 39 pp.

The experience at Oak Ridge National Laboratory in decontamination equipment and working areas are summarized.

AECD-4083

Webster J W
PRACTICAL REACTOR THEORY,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 21, 1953, 146 pp.

The purpose of this writing is to provide a practical type of text in reactor theory for the use of nuclear engineers engaged in reactor design. Methods are derived for calculating critical mass; power distribution; reactivity effects of temperature; depletion, and fission-product poisons; the necessary number of control rods to compensate for these effects; and the kinetic behavior of flux and temperatures in a reactor with regard to reactor stability and self-regulation.

It is the opinion of the author that methods in the field of reactor theory must be short and simple in application if they are to be of real assistance to reactor design. An answer that can be obtained in a day or two with an accuracy of 50% is often very useful to a designer, whereas one that is accurate to within 10% but takes a month to obtain may be obsolete and utterly useless by the time it is presented to the designer by the physicist.

An understanding of fundamental ideas such as cross section and mean free path are assumed here. An excellent reference for such definitions is Part I of TID-384 by Glasstone and Edlund.

The subjects discussed in this report, in the order listed, are:

1. The one-group theory for the calculation of critical mass and power distribution. The one-group model is very crude and is given partly for pedagogical reasons, but it does have practical usefulness.

2. The Fermi age theory for calculating critical mass. The Fermi age theory is one of the most useful approaches to critical mass determination, in spite of the fact that it can be applied only to unreflected reactors. The reflected reactor can be approximated by an equivalent unreflected reactor, as discussed in Chapter 2. The formulas obtained by Fermi age theory are simple and relatively accurate for reactors moderated with beryllium or carbon, and a modification of the formulas can be applied to make the method reasonably accurate for hydrogen-moderated reactors.

3. The two-group theory for calculating critical mass and power distribution. The two-group model can be used in conjunction with the Fermi age method by determining the core constants for the former by means of the latter. This is discussed in Chapter 3.

4. The effect of temperature, depletion, and fission-product poisons, such as xenon and samarium. These effects act to decrease the effective neutron multiplication constant, and therefore the fuel inventory must be sufficient to ensure criticality when these effects are at their maximum.

5. The necessary number of control rods (shim rods) to offset the virtual supercriticality that exists in a reactor at startup when the effects described in Item 4 are at a minimum.

6. The kinetic behavior of flux and temperatures in a reactor. The kinetic self-regulation, stability to accidents, and response to control rod (regulating rod) motion must be investigated for a reactor design proposal.

AECD-4240

BOBBY TRAPS,
Talk for Pittsburgh Meeting of American Nuclear Society, June 12, 1957, 18 pp.

This paper outlines briefly the situations that have led to accidental prompt-critical radiation bursts (nuclear accidents) in critical assembly laboratories, and mentions a few others that appear to be risky.

AECD-4262

FUNCTIONAL REQUIREMENTS FOR THE PWR CONTROL ROD MECHANISM,
Atomic Power Div., Westinghouse Electric Corporation, Pittsburgh 30, Pa., 20 pp.

This report covers two topics: (1) functional requirements for control rod drive mechanisms and (2) supplementary design information for control rod drive mechanism. The information in the above two topics is presented in the form of two check lists whose items define the functional requirements of these mechanisms. Also, three appendices are included which serve to amplify and explain the data contained in the check lists.

AECL-220 CRR-590

CATALOGUE OF NUCLEAR REACTORS,
Atomic Energy of Canada Limited, Chalk River Project, Chalk River, Ontario, August (1955).

This catalogue has been compiled from the unclassified literature and refers to reactors which are known to have reached criticality by July 1955. Additions and revisions will be prepared as they become necessary to keep the collection up-to-date.

This catalogue gives information on classification which covers neutron speed, fuel configuration, kind of moderator, purpose, thermal power, and neutron flux; and construction details.

AECL-252 DL-20

Lewis W B
REACTOR DESIGN AND TECHNOLOGY PRESENTED AT THE UN GENEVA CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY, AUGUST, 1955,
Atomic Energy of Canada Limited, Chalk River Project, Chalk River, Ontario, August (1955), 16 pp. (36 refs).

This report discusses hazards of reactor fission products as a result of a reactor explosion or accident. It is pointed out that any reactor explosion would at the most be no greater than an ordinary chemical explosion. However, the resulting danger would be from possible escaping fission products.

Coolant categories such as gas, water, liquid, metal, and organics are discussed qualitatively. The ideal coolant is not known.

It is pointed out that nuclear physics requirements affect mainly the choice of reactor materials and the choice of fuel cycles.

AECU-2900

Grigorieff W W (Editor)
PROCEEDINGS UNIVERSITY RESEARCH REACTOR CONFERENCE,
Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn., February 17-18, 1954, 221 pp.

The proceedings of the University Research Reactor Conference held in Oak Ridge cover the material presented in the formal papers, in the round table discussions, and in the question periods of the conference. The formal manuscripts and the verbatim recordings of the meeting have been reviewed by the authors, compiled and edited by the Institute staff, and represent a complete summary of the information made available by the conference.

AECU-3062

Davis Frank W
FEASIBILITY STUDY OF PRESSURE VESSELS FOR NUCLEAR POWER GENERATING REACTORS,
Engineering Branch, Division of Reactor Development, USAEC, Washington, D.C., December (1955), 366 pp.

All power generating nuclear reactor concepts include the use of pressure vessels. In many cases the vessels indicated are of unconventional design. Large volumes and high pressures are involved. Because of these factors the several groups studying the problems involved in producing economical nuclear power have experienced difficulty in evaluating proposed pressure vessel design from either the standpoint of feasibility or cost. In order to assist the study groups the Engineering Branch of the Reactor Development Division undertook a study of pressure vessel design as applied to nuclear power development. Since it is recognized that manufacturers of large pressure vessels are best qualified to evaluate special design problems, three representative companies were selected for this phase of the program. Four design concepts for pressurized water reactors which has been submitted by two of the study groups as being representative of present thinking were selected on this basis for the study.

This study consists of four reports which are:

1. "Design, Fabrication and Feasibility Studies of Four Reactor Pressure Vessels for United States Atomic Energy Commission," Combustion Engineering, Inc., N. Y., Contract No. AT-(30-3)-147, pp. 1-110, October 30, 1954.

   This report contains detailed information with respect to examination and verification of service requirements by stress analysis methods, determination of design details necessary for improved fabrication procedures, preparation of the anticipated fabrication procedures, and estimates of cost of final design and fabrication for each of the pressure vessels. While this study was carried out by reference where applicable to Section VIII of the Unfired Pressure Vessel Code of the American Society of Mechanical Engineers, it is strongly recommended that vessels of this nature be constructed in accordance with Section I, the Power Boiler Code of the American Society of Mechanical Engineers.

   It is believed that little value would be obtained from studies carried out beyond the range reported here. While the report points out the areas in which development work on fabrication procedures might be carried out, the full usefulness of such work would be best obtained in reference to vessels actually to be constructed and utilized.

2. "Report on Feasibility Study of Pressure Vessels," conducted by The Midvale Company in collaboration with The Franklin Institute, Contract No. AT-(30-3)-145, pp. 111-224, March 12, 1954 to January 31, 1955.

   This contract encompasses design and fabrication feasibility studies of four pressure vessels whose basic design features were transmitted by the AEC. These vessels are well suited to production facilities as now designed. No way was found to overcome the objection of having stainless steel tubes welded into the heads and tube sheets.

3. Pfeiffer, L. G., "Reactor Vessel Study," Process Equipment Division, A. O. Smith Corporation, Milwaukee, Wisconsin, Contract No. AT-(11-1)-290, pp. 225-354, June 15, 1955.

   An engineering study covering the mechanical design, manufacturing procedures, and cost estimates for three reactor vessels based on specified diameters, lengths, number and size of openings, and fixed opening locations for specified operating pressures and temperatures, both for specified operating pressures and temperatures, both for single plate and multilayer construction.

   The mechanical designs and manufacturing procedures are based upon standard present day manufacturing facilities following the 1952 ASME Unfired Pressure Vessel Code where applicable, particularly the formulas for obtaining shell and head thicknesses and reinforcing requirements for openings. Any specifications or modifications necessary to meet nuclear requirements, such as special inspections and cleaning standards are not included in this design.

4. Fratcher, G. E., "The Influence of High Strength Materials on the Design and Fabrication of Layer Vessels," American Society of Mechanical Engineers, Petroleum Division Conference, Los Angeles, Calif., September (1954), pp. 355-366, this report.

A multilayer vessel is defined as a vessel whose cylindrical portion is made up of two or more contacting bands or layers. This report gives a description of multilayer vessels and characteristics of such vessels; and discusses layer materials and development of high strength materials for super pressures.

AECU-3320 INTERNUC-3

PRELIMINARY DESIGN STUDY OF A FOOD IRRADIATION REACTOR. Phase 2, Internuclear Co., Inc., Clayton, Mo., July 1, 1956, 92 pp.

In April 1956, the Army Reactor Branch of the Division of Reactor Development of the AEC, through the Schenectady Operations Office, requested Internuclear Company to select the most promising reactor type for production of gamma radiation in a pilot plant for the food irradiation program of the Army Quartermaster Corps and further, to make a preliminary design study of the system selected to the point where the major research, development , design, and operational problems foreseen in the design, construction, and operation of the reactor-radiator complex could be pointed out. This report presents a preliminary design study of the selected reactor type.

The general design features of the reactor-radiator complex described in this report are based on providing a system that is relatively simple and does not require extensive reactor developmental work. The reference reactor is intended to serve as a basis for future optimization through detailed study of the many parameters affecting efficient generation and use of the gamma energy, and is not to be considered as an already optimized system.

The reactor-radiator complex described herein is not an "optimum" for this type of system. Optimization of the design requires more detailed heat transfer and nuclear calculations as well as a thorough study of the factors which affect the over-all efficiency of the unit. The latter includes:

a. Production, dose, and dwell time specifications
b. Size and composition of reactor core
c. Blanket tank materials and size
d. Indium solution concentration
e. Reflector (and thermal shield) material and placement
f. Blanket and indium solution cooling
g. Radiator geometry, size, volume
h. Size and shape of food packages or items

The inherent reactor safety aspects of this system are favorable. Even rapid loss of all indium from the indium solution blanket presents no serious hazards. The remaining safety characteristics are quite similar to the MTR type reactor.

The major problems foreseen in the design, construction, and operation of the complex are in the gamma radiator and its loop. They are the chemical behavior of the water indium sulfate loop, i.e., corrosion, crudding, stability under irradiation, and decontamination; maintenance and repair of the indium loop; and the calculation and later actual measurement of max/min gamma dosages within the food. There do not appear to be any major problems connected with the reactor portion, although a critical experiment to optimize fast neutron leakage should be made.

AECU-3427 INTERNUC-9

Elgert O J, Leyse C F and Ott D G
PRELIMINARY INVESTIGATIONS FOR AN ADVANCED ENGINEERING TEST REACTOR,
Internuclear Company, Inc., Clayton, Missouri, February 22, 1957, 124 pp.

A study was carried out to determine a suitable reactor system or systems for the testing of water, gas, and liquid-metal cooled fuel assemblies. The unperturbed thermal neutron fluxes in the test holes are to be 1 - 1.5 x 10^{15} n/cm^2-sec. A group of seven separately cooled and controlled reactors assembled in a common shield are proposed to meet the test facility requirements. Each of the reactors consists of the central test thimble, surrounded consecutively by an H_2O annulus, reactor core, and D_2O reflector. The estimated total power of the seven reactors is about 450 Mw when the neutron flux requirements are met in all the test holes.

For a more detailed reactor design see AECU-3427 (add.).

AECU-3427 (Add.) INTERNUC-9 (Add.)

Leyse C F and Leonard B H, Jr.
PRELIMINARY INVESTIGATIONS FOR AN ADVANCED ENGINEERING TEST REACTOR,
Internuclear Company, Inc., Clayton, Mo., April 16, 1957, 12 pp.

On February 22, 1957, Internuclear Company in fulfillment of Contract No. AT-(11-1)-500, submitted a report entitled "Preliminary Investigations for an Advanced Engineering Test Reactor"* to the Atomic Energy Commission. Because of the interesting and unique reactor features which evolved from that study, and to further demonstrate the practicability and desirability of the facility recommended in that study, Internuclear Company decided to carry the design into a more detailed stage. It is the purpose of this report to present the results of this additional work and to illustrate the refinement of design.

*INTERNUC-9.

AECU-3526

OPERATING MANUAL FOR THE CP-5 REACTOR,
Laboratory Research Reactor Operations Division, Argonne National Laboratory, Lemont, Illinois, January 1, 1956, 29 pp.

To assure safe and reliable operation of the CP-5 Argonne Research Reactor, certain test procedures, work area checks, routine inspections and operational practices have been established as the rules concerning the operation of this reactor. These rules are set forth in this operating manual.

AECU-3559

Thompson A S
GAS COOLED NUCLEAR REACTOR STUDY,
Nuclear Power Department, Studebaker-Packard Corporation, Detroit, Mich.,
Contract No. AT(30-3)-214, July 31, 1956, 105 pp.

The investigation covered by this report contains two main parts. An investigation was made of the performance of a gas-cooled reactor, designed to provide a source of high temperature heat to a stream of helium. This reactor, in turn, is used as a source of heat for the air stream in a gas-turbine power plant. The reactor design was predicated primarily on the requirement for transferring a large amount of heat to the helium stream with a pressure drop low enough that it will not represent a major loss of power in the power plant. The mass of uranium required for criticality under various circumstances has been investigated by multigroup calculations, both on desk calculators and on an IBM-704 machine. The gas turbine power plant performance was studied based on a Studebaker-Packard-designed gas-turbine power plant for the propulsion of destroyer-escort vessels. A small experimental program was carried out to study some effects of helium on graphite and on structural steels.

AECU-3600 CU-34-57-AT-187-Ch.E

Stein Ralph P
TRANSIENT HEAT TRANSFER IN REACTOR COOLANT CHANNELS,
Engineering Research Laboratories, Columbia University, N.Y., N.Y., Contract No. AT-(30-3)-187, October 31, 1957, 39 pp. (7 refs).

An analysis is presented of the transient behavior of a generalized coolant channel neglecting temperature dependent reactivity changes. The analysis is applicable to forced conviction cooling of heterogeneous reactor fuel elements or electrically heated simulation thereof. Derivations are given for cases of variation of coolant inlet temperature and of heat generation. An approximation is also developed applicable to thin fuel elements. From this, solutions are obtained for cases of impulsive, step, linear, and step-exponential variations of inlet temperature, and, of impulsive and uniform variations of heat generation. The solutions presented will be of use during preliminary stages of design of new heterogeneous reactor concepts (when the use of computing machines may not be warranted), and, in the design and interpretation of transient experiments simulating reactor fuel channels.

AERE-C/R-1715

Lock C J L
FISSION PRODUCT FORMATION IN A HOMOGENEOUS POWER REACTOR,
Atomic Energy Research Establishment, Harwell, Berkshire, England, June 28, 1955, 41 pp.

Calculation has been made of the weight, activity and total neutron absorption cross section of the individual fission product isotopes present after irradiating a mass of uranium (U^{235}) for periods of 3, 6, 9, and 12 months at a neutron flux of 10^{15} n/cm^2-sec., the mass of uranium being maintained at one kilogram. An indication is given of the way in which these results can be applied to a homogeneous reactor.

Tables of data are included which cover the following topics: fission chains; weights, activities and cross section of fission products; weights of fission products formed assuming no neutron capture takes place; weights of fission products in groups in order of increasing weight; total capture cross section of fission products in groups in increasing order; activities of the fission products arranged in groups in order of increasing activity; and activity of fission products after 90 days irradiation and 3 months, 1 year and 20 years decay.

AERE-ES/M-27

Williams K J
DIDO REMOTE ACTIVE HANDLING FACILITY - FEEL-UNIT,
Atomic Energy Research Establishment, Harwell, Berkshire, England, June (1958), 12 pp.

This memo describes the unit which was developed to provide the operator of the Overhead Manipulator with a sense of "feel" during various operations with the manipulator.

AERE-HP/M-109

Chamberlain A C and Megaw W J
SAFE DISTANCES IN REACTOR SITING,
Atomic Energy Research Establishment, Harwell, Berkshire, England, July (1956), 22 pp. (12 refs).

In this paper the assumptions and calculations used in deriving British reactor safety distances are reviewed, with particular reference to the possible errors. Much of the material has been presented previously. The present paper includes some new data on analysis of old data on travel and depositing of clouds in Appendix I and II, but the main object is to estimate the degree of possible error in the conclusions on which the U.K. siting policy is at present based.

AERE-R/R-2108

Newmarch D A
THEORETICAL THERMAL NEUTRON FLUX DISTRIBUTION IN EMPTY CHANNELS IN REACTORS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, December 30, 1956, 28 pp.

By means of the spherical harmonics method, expressions are derived for the thermal neutron flux distributions in the air channels of reactor assemblies where the fuel elements are in the form of cylindrical rods and tubes.

These expressions have been evaluated for a few cases of graphite moderated assemblies.

AERE-RE/R-1684

Jackson R F
A POSSIBLE ARRANGEMENT OF A SWIMMING POOL TYPE EXPERIMENTAL REACTOR,
Atomic Energy Research Establishment, Harwell, Berkshire, England, May 19, 1955, 13 pp.

It is clear that there will be an increasing demand from universities and research establishments for a cheap and flexible reactor giving a maximum flux of from 10^{12} - 10^{13} n/cm^2-sec.

This report relates to a preliminary design study of a general use experimental reactor of the swimming pool type in which an attempt has been made to provide as wide a range of experimental facilities as possible at reasonable cost. The treatment is not exhaustive and many variants are possible on the general theme.

Highly enriched fuel elements are used with a normal flux 10^{12} n/cm^2-sec corresponding to a heat output of 100 kw while the possiblility of operation at 1 Mw is also discussed.

The engineering design is intended to allow considerable prefabrication and mechanical test at the manufacturers works and to reduce specialized work on site to a minimum in a way which would be advantageous for erection overseas.

AERE-RP/R-2031

Campbell C G and Freemantle R G
EFFECTIVE CROSS-SECTION DATA FOR THERMAL REACTOR CALCULATIONS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, July (1957),
4 pp. (7 refs).

This paper contains two tables of cross-section data for thermal reactor calculations.

AGN-0857

AGN ANNOUNCES THE FIRST COMPLETE REACTOR LINE,
Aerojet-General Nucleonics, San Ramon, Calif., August (1957).

This is an advertisement which announces a complete line of mass produced nuclear reactors. Also included is a reprint from Nucleonics.

Biehl, A. T., et al., "Compact, Low Cost Reactor Emphasizes Safety,"
Nucleonics, Vol. 14, No. 9, pp. 100-103, September (1956).

This paper discusses a small research reactor designed for use in education, research, medical diagnosis, and industrial process control.

AIF-57-23

Trilling Charles
ORGANIC MODERATED REACTOR EXPERIMENT,
Atomics International, North American Aviation, Inc. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, N.Y., October (1957), 12 pp.

This paper is a report on the operating experience of the Organic Moderated Reactor Experiment (OMRE). Most of the experience reported here is concerned with the pre-operational testing of the installation. A brief description of the present status of OMRE is also presented.

AIF-57-37

Stockman Charles M, Dr.
THE ECONOMICS OF RADIATION PROCESSING,
B. F. Goodrich Research Center. Published by Atomic Industrial Forum, Inc.,
3 East 54th St., New York 22, N. Y., October (1957), 12 pp.

This paper discusses the general aspects of the economics of radiation processing. There has been a great deal said about what radiation can do to provide new and improved products, but not very much has been said about how much it might cost to provide the radiation. For all the publicity given the radiation business the number of radiation treated products available is surprisingly small. To obtain economy in commercial radiation processing operations, radiation machines should be selected specifically for the jobs they will do.

Radiation processing is still in its early infancy. It shows much promise, but its high cost as a process tool has hindered its growth. Continued research should alter this situation, at least in some areas. For the present, however, radiation must be considered an expensive tool, one which will be used only when it can provide a premium product or do a job which cannot be done economically by any other means.

AIF-57-75

Montgomery Hugh
PRODUCTION EXPERIENCE WITH THE AGN-201 REACTOR,
Aerojet-General Nucleonics. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, N.Y., October (1957), 6 pp.

Aerojet-General Nucleonics, a subsidiary of the Aerojet-General Corporation, has designed and is producing a low power portable nuclear reactor, the AGN-201. The primary use of this reactor has been for training, but other applications have been devised and at least one unit has been installed for the purpose of producing short half-life radioisotopes. This is the first nuclear reactor in the world to be built on a production line basis. This paper specifically discusses prototype design and unique aspects of reactor fabrication.

AIF-57-80

Nixon V D
TRAINING REACTOR OPERATORS,
General Electric Company. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, N.Y., October (1957), 7 pp.

One of the important new areas of the nuclear power industry today concerns the planning for the safe and efficient start-up and operation of the various nuclear plants which are now being built. Commonwealth Edison and General Electric have been jointly giving careful consideration to the organization of the Dresden Station and to the training of its personnel. This paper reviews the main features of the Dresden plant and discusses what is being done to assure the smooth operation of the plant from the personnel standpoint.

AIF-57-104

Rosenbluth Marshall
PROBLEMS OF FUSION REACTORS,
General Dynamics Corporation. Published by Atomic Industrial Forum, Inc., 3 East 54th St., New York 22, N.Y., October (1957), 12 pp.

The principal problem to date is that there is not a fusion reactor in operation. This paper explains what the difficulties are, how these difficulties are being met, and what the prize for success would be. Also discussed is the fusion process.

AIF-57-107

Chastain Joel W, Jr.
TRENDS IN RESEARCH REACTORS,
Battelle Memorial Institute. Published by Atomic Industrial Forum, Inc.,
3 East 54th St., New York 22, N.Y., October (1957), 11 pp.

This paper presents a description of the basic types of research reactors. By pointing out the research facilities incorporated in these basic types, their areas of potential usefulness are made clear.

A brief discussion of the costs for the various research reactors is presented. Some trends in operational and research costs for research reactors are also included.

The operational procedure for the Battelle Research Reactor is described in this paper. This "typical" procedure gives an insight into the regulations provided to insure a safe reactor operation.

AIF-57-108

Eukel Warren W
ACTIVITIES OF A COMMERCIAL IRRADIATION SERVICE CENTER,
Applied Radiation Corporation. Published by Atomic Industrial Forum, Inc.,
3 East 54th St., New York 22, N.Y., October (1957), 11 pp.

The comments in this paper are directed to the use of a service facility for developing and expanding irradiation applications. The information presented is based primarily on experience with the commercial irradiation service facility at the Applied Radiation Corporation plant in Walnut Creek, Calif. Specific topics discussed are purposes of irradiation service centers and different types of programs undertaken in those facilities. Ultimately, service irradiation may develop into an industry itself, since many companies may find it advantageous to participate in a joint venture to operate a common facility.

AMF-GR-8-56

ELECTRONIC REACTOR CONTROL SYSTEMS,
American Machine and Foundry Company, Greenwich Laboratories, Greenwich, Conn.,
May (1956), 7 pp.

During the more than fifteen years that AMF has been actively engaged in the Atomic Energy field, special emphasis has been placed on the design and development of complete reactor control systems. Through actual experience with control systems on equipment for power, production, and research reactors, an intimate working knowledge of the unique problems of nuclear reactor controls has been gained.

The type of control system recommended for research reactors is described in this report. This system can be adapted to any type of research reactor, and employs all the features necessary for safe, reliable, and accurate reactor control.

AMF-GR-14-55

Poindexter A
AMF RESEARCH REACTOR POOL-TYPE TECHNICAL DISCUSSION,
American Machine and Foundry Company, Greenwich Laboratory, Greenwich, Conn., January (1956), 40 pp.

The AMF pool-type research reactor is a light-water-moderated, heterogeneous, solid fuel reactor in which water is also used for cooling and shielding. The reactor core is immersed in a two-section concrete pool filled with water. One of the sections of the pool contains an experimental stall into which beam tubes and other experimental facilities converge. The other section is an open area for making bulk irradiations. The reactor can be operated in either section.

Control of the reactor is accomplished by the temperature coefficient of reactivity and by insertion or removal of neutron-absorbing control rods suspended from control drives mounted on the bridge. The reactor furnishes a high intensity source of neutrons and gamma rays of all energies for experimental use.

This report gives a detailed description and discussion of reactor core, reactor control, pool and experimental facilities, and cooling and purification system.

ANL-4294

Harrer J M
NUCLEAR REACTOR SIMULATOR,
Argonne National Laboratory, Lemont, Ill., Contract No. W-31-109-Eng-38, June 1, 1949, 101 pp.

The purpose of this report is to describe the work done at Oak Ridge National Laboratory in the development of a nuclear reactor simulator. This work is part of the total program of the Power Pile Division and was carried on by the Control Section. The advantages to be gained from having available a simulator were sufficient to warrant directing the persons involved to put as much effort as possible into its development.

A great deal has been learned about the possibilities of such a simulator and the difficulties which are encountered in its design. In this report no attempt is made to draw any definite conclusions.

The simulator is an electrical analogue computer. If due consideration has been given to keeping the model similar to the physical phenomena described by the differential equations, the practical engineer has at his disposal a means of studying the physical phenomena without continued reference to the differential equations involved. The simulator developed at ORNL meets this requirement. It consists of a network of electrical conducting elements and suitable sources of current and current sinks. The design of this network is such that when the proper electrical resistance values are assembled and the current sources and sinks are properly adjusted, the steady-state voltage distribution on the network is the same as the steady-state flux distribution in the reactor and the current sources are a measure of the critical mass of the reactor.

This report discusses network development which covers the derivation of formulae for the relations between reactor constants and electrical network constants; construction of experimental networks which describe the networks used to determine the feasibility

of the simulator; current feeding equipment which gives a description of the methods used to feed electrical current, which simulates the birth of neutrons in the reactor, into the electrical network; and experiment and development work which describes some of the ideas which were tested during the development period.

ANL-4551 ANL-SM-122

Winkleblack R K
EXPERIMENTAL FACILITIES PROVIDED IN THE MATERIALS TESTING REACTOR, Materials Testing Reactor Project, Argonne National Laboratory, P.O. Box 5207, Chicago 80, Ill., Contract No. W-31-109-Eng-38, December 29, 1949, 39 pp. (6 refs).

The purpose of this report is to present to the scientists working in the Atomic Energy field a survey of the facilities that will be provided in the Materials Testing Reactor. A brief description of the general site of the reactor's facilities, and a brief description of the laboratories and shops to be provided with the reactor are included along with a detailed description of the experimental facilities.

ANL-5211

Dietrich J R and Layman D C
TRANSIENT AND STEADY-STATE CHARACTERISTICS OF A BOILING REACTOR, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, February (1954), 141 pp.

The characteristics of transient and steady-state boiling in a water-cooled, water-moderated reactor have been investigated in a reactor which was set up and operated at the Reactor Testing Station during the Summer and Fall of 1953.

In a series of about 70 intentional "runaway" type tests it was demonstrated that the formation of steam and consequent ejection of water from the reactor core can provide inherent protection against the runaway hazard in suitably designed reactors of the water-cooled, water-moderated (H_2O or D_2O) type. Power excursions of periods as short as 0.005 second (2.1% excess reactivity in the experimental reactor) were terminated by this process. Although the maximum power in the excursions went as high as 2600 megawatts, fuel plate temperature never exceeded 640°F. Maximum power, total energy liberation, and fuel plate temperatures were investigated at atmospheric pressure as functions of excess reactivity in the excursion and initial reactor temperature.

Operation of the reactor in steady boiling at pressures up to 130 psig and powers up to 1200 kw demonstrated that quite smooth operation is attainable up to the point where the steam content of the reactor represents about -2% k_{eff} in reactivity. At higher steam contents characteristic power fluctuations were observed. The reactor steam power was shown to be self-regulating. The effects of various operating conditions and system variables on reactor power and operating characteristics were investigated.

Results of the investigation are believed to point the way toward more economical power reactors through minimization of the hazard problem, simplification of reactor design, and reduction of the temperature demands on reactor materials.

Four appendices are included. These are "Detailed Composition and Calculated Nuclear Constants of Borax Reactor"; "Transient Instrumentation"; "Power Calibration of Ion Chambers"; and "Measurement of Steam Flow Through an Orifice at Critical Pressure."

ANL-5361

Diamond Herbert and Barnes Raymond F
PRODUCTION OF Pu^{246} IN THE MTR,
Chemistry Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill.,
Contract No. W-31-109-Eng-38, November (1954).

This is a short paper (3 pages) which describes the production of Pu^{246} in the MTR.

ANL-5403

Fromm L W
DESIGN EVALUATION OF IN-REACTOR TUBE FOR ARGONNE WATER LOOP AT MTR (ANL-2),
Reactor Engineering Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill.,
Contract No. W-31-109-Eng-38, March (1955), 44 pp. (25 refs).

A rigorous stress analysis is performed on a presurized, in-reactor tube test facility (Type 347 stainless steel tube with Type 316 tip) to ensure conformity of the design with ASA and ASME Codes. Detailed calculations, along with tabulated and graphical data, show that the maximum membrane stress (14,200 psi) and the combined membrane and thermal stresses (22,200 psi) are well below the yield point of the steel. Calculated thermal gradients are lower than those accepted in commercial practice. Experimentally determined stresses and temperature gradients verify or are more favorable than corresponding calculated values.

Radiation damage data are presented to show that even at saturation levels, the properties of Type 300 series stainless steels do not approach the limits at which embrittlement failure might be anticipated.

ANL-5424

McLain Stuart
REACTOR ENGINEERING LECTURES,
Argonne National Laboratory, Lemont, Ill., Contract No. W-31-109-Eng-38,
March (1955), 353 pp.

The twenty-eight lectures contained in this report were prepared from notes used in a classified course in Reactor Engineering given at Argonne National Laboratory from September 1953 to June 1954. An attempt was made to present the principles involved rather than to cover all of the facts relating to the various subjects.

The following is a list of the topics covered in these lectures:

1. Nuclear Engineering
2. Thermal vs Fast Reactors
3. Light and Heavy Water Reactors
4. Hanford and Savannah River Reactors - Graphite Reactors
5. Homogeneous Reactors
6. Industrial Study Group Reports
7. Boiling Reactors
8. Fluid Flow
9. Heat Transfer
10. Materials
11. Preparation of Pure Materials
12. Preparation of Alloys - Phase Diagrams
13. Preparation of Fuel Elements
14. Corrosion of Reactor Materials
15. Radiation Damage
16. Maintenance of Coolants
17. Xenon and Samarium; Changes in Reactivity

18. Reactor Control
19. Shielding, Gamma-Ray Heating
20. Seals, Pumps, Heat Exchangers
21. Loading, Unloading, Cooling after Shutdown
22. Operational Problems
23. Economic Considerations
24. Principles of Solvent Extraction
25. Engineering and Solvent Extraction Design
26. Solvent Extraction Processes
27. Metallurgical Processes
28. Effluent Control

ANL-5491

Okrent D (ANL) and Shepherd L S (AERE)
JOINT STATUS REPORT ON FAST REACTOR PHYSICS,
Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, October (1955), 3 pp. (3 refs).

The authors have jointly examined the status of fast reactor physics in the United Kingdom and the USA and find a gratifying degree of agreement. This agreement appears not only in the final performance figure, but also in the detailed analysis of a direct comparison of British measurements and American expectations of the breeding ratio of an assembly such as the Zephyr. This report briefly discusses and compares the status of fast reactor physics in the two countries.

ANL-5607

THE EXPERIMENTAL BOILING WATER REACTOR,
Argonne National Laboratory, May (1957), 231 pp.

This report describes the final design of the Argonne Experimental Boiling Water Reactor (EBWR) Power Plant. All phases of the power plant from its inception to final design are discussed and the theory and operational problems stated. The final design of the EBWR is a 5 megawatt, enriched uranium, light water moderated reactor.

ANL-5647

Lennox D H and Kelber C N
SUMMARY REPORT ON THE HAZARDS OF THE ARGONAUT REACTOR,
Reactor Engineering Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, December (1956), 106 pp.

This report covers installation of an Argonaut Reactor at the Du-Page site of the Argonne National Laboratory. The reactor is to be operated by trained members of the staff, assisted by other laboratory personnel, and by students at the International School of Nuclear Science and Engineering, as a facility for nuclear engineering training and research. The design anticipates use of an Argonaut reactor in universities and in other less specialized institutions. Therefore, safety is a prime design feature through choice of a self-limiting system.

Argonaut is a 10-kw (max.) thermal reactor moderated by water and reflected by graphite. Plant-type fuel elements are spaced with graphite wedged to form an annular core. The total fissionable material required is about 4 kg U^{235}. The experimentally determined void coefficient for the lattice is negative: -0.25% k per void per cent. The

temperature coefficient is also negative: -10-4 k/C. Excess k is less than 0.75%. Rapid insertion of up to 4.75% k_{ex}, possible only by deliberate circumvection of procedures, interlocks, trips, and controls, will result in automatic shutdown through a nondestructive BORAX-type process. This postulated situation will not result in over-exposure of personnel near the reactor or contamination of the immediate vicinity. Complete release of fission products contained within the fuel plates by some process not easily imagined would require an exclusion radius of 875 ft, assuming no building containment.

This report does not consider internal multiplicative experiments which could be performed by reloading the internal reflector. Such experiments must be subject to a separate hazards review.

ANL-5651

Porzel F B
DESIGN EVALUATION OF BER (BOILING EXPERIMENTAL REACTOR) IN REGARD TO INTERNAL EXPLOSIONS,
Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, January (1957), 108 pp.

An analysis of the safety aspects of the Argonne National Laboratory Boiling Experimental Reactor with regard to internal explosion has been made. On the basis of this analysis the reactor has been adjudged reasonably safe for the estimated release of 0.8×10^{8} calories.

The analysis covers the effect of a blast wave in free concrete, with detailed consideration of the shock wave equations of motion and the equation of state for solids. The impulse delivered to a surface from various pressure decay laws and the energy dissipation due to waste heat is presented in detail.

Since the Boiling Experimental Reactor is surrounded by water, the reflection and transmission of shock waves at a water-concrete interface is treated very generally in the report. From a study of the rates of energy transfer across such interfaces and the resulting shock wave diffraction patterns, a protection scheme is developed.

The various methods by which protection from shock waves can be provided are examined, and it is shown that a new type blast shield would be the most practical solution. The general background of the blast shield design is developed and the mechanism of absorption is discussed.

The design rules are then applied to the Boiling Experimental Reactor and a blast shield of the proper materials and dimensions is developed. This design makes use of the properties of a number of materials from Celotex to concrete and will reduce the shock wave impulse below that which might damage the reactor structure.

ANL-5657

REACTOR ENGINEERING DIVISION QUARTERLY REPORT - SECTION II,
Reactor Engineering Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, December (1956), 68 pp.

This report summarizes the Advanced Water Reactor Program and the Fast Breeder Reactor Program. Most of the work on the Advanced Water Reactor Program involved completion of fabrication, installation, and checking out of equipment. Therefore, this report is a brief summary only and details of significant events will appear in the next Quarterly Report (October, November, and December 1956). A more detailed discussion is included on the Experimental Breeder Reactor II (EBR-II). This discussion includes coolant flow characteristics of the primary system, reactor temperatures and fuel expansions, and information of three pump systems.

Additional supporting work is reported on. This work includes S_4 calculations to investigate inhomogeneities in ZPR-III assemblies; effect of high temperature on irradiated fission alloy; evaluation of gears and bearings for service in sodium at elevated temperatures; bellows seal and sodium condensation test; and sodium-air reaction experiments.

ANL-5688

Link L E, et al.
THE MIGHTY MOUSE RESEARCH REACTOR PRELIMINARY DESIGN STUDY,
Reactor Engineering Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill.,
Contract No. W-31-109-Eng-38, March (1957), 84 pp.

The design of a 250-mw heterogeneous reactor, with a peak thermal neutron flux level of about 5×10^{15} n/cm^2-sec, is proposed for basic research, neutron-beam experimentation, and irradiation studies at an Argonne site.

The design concept features a D_2O-cooled, moderated, and reflected annular core (30 cm ID, 90 cm OD, 90 cm high) of highly enriched, magnesium-clad fuel element contained in a pressure vessel approximately 13 ft in diameter.

Included are the results of preliminary studies directed toward establishing the avenues of research and development necessary to resolve the problems of heat transfer, fuel fabrication and handling, control, and shielding inherent to the proposed reactor operating cycle of 5 days.

Three appendices are included. These are "Summary of Preliminary Calculations of Xenon and Iodine Concentration in the Mighty Mouse Reactor"; "A Two-Group Iteration Method for Annular Cylinders"; and "Specifications for Burnable Poisons."

ANL-5719

Koch L J, et al.
HAZARD SUMMARY REPORT EXPERIMENTAL BREEDER REACTOR II (EBR-II),
Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38,
May (1957), 384 pp. (11 refs).

Argonne National Laboratory proposes to construct an Experimental Fast Power Reactor at the National Reactor Testing Station in Idaho, as a part of the Atomic Energy Commission's program for the development of power reactors.

The Experimental Breeder Reactor II (EBR-II) is an unmoderated, heterogeneous, sodium-cooled reactor and power plant with a power output of 62.5 megawatts (mw) of heat. The energy produced in the reactor is converted to 20 mw of electricity through

a conventional steam cycle. The reactor is fueled with U^{235} or plutonium, and the plant includes an integral fuel processing facility where the irradiated fuel is processed, fabricated, and assembled for return to the reactor.

The EBR-II reactor consists of an enriched core surrounded on all sides by a fertile blanket of depleted uranium. The fuel elements which comprise the core section of the reactor consist of small diameter cylindrical pin assemblies. The design of the fuel element is influenced by the desire for high thermal performance, high burnup, and simplicity of construction. The fuel pin is a loose fit in a thin-walled tube which provides a clearance annulus between the pin and the tube wall. This annulus is filled with static sodium to provide a heat transfer bond between the fuel and fuel tube. Heat is removed from the fuel element by the primary sodium flowing along the outside of the fuel tube. The fuel element lends itself to fabrication by remote control methods as required by the particular fuel process selected. Of particular significance is the fact that complete decontamination of the fuel is not obtained. Certain fission product elements, notably molybdenum and ruthenium, are not removed, and because of the high fission yield of these elements, they tend to build up in significant concentration in the fuel alloy. The fuel alloy to be employed in the EBR-II, therefore, is established by the fuel process; fortunately, it appears to exhibit irradiation damage stability and thermal cycling stability. To avoid large changes in alloy composition with each fuel cycle, the reactor will be loaded initially with a synthetic alloy approximating the equilibrium composition, and consisting of enriched uranium plus approximately 5% (by weight) of synthetic fission products. (Provisions are made to permit subsequent loading of the reactor with plutonium-uranium alloys. The fuel process and fabrication cycle is adaptable to this fuel system and the addition of fission products appears to enhance the stability and fabricability of the alloy.)

The reactor operates with a maximum power density in the core of approximately 1370 kw/liter with a maximum coolant velocity of 26 fps, and reactor coolant temperatures of 700°F inlet and 900°F outlet. Reactor control is effected by the movement of fuel into and out of the reactor core. This is accomplished by 12 modified movable fuel subassemblies which move vertically and are located at the outer edge of the core.

Heat is removed from the reactor by the primary sodium coolant system and transferred to the secondary sodium system in a shell-and-tube heat exchanger. The secondary system transfers the heat to the steam generator where superheated steam is produced to drive a conventional turbine-generator.

The reactor and the entire primary coolant system, including heat exchanger, are contained in a large vessel (primary tank) and operate completely submerged in the coolant. This provides a high degree of reliability of containment of the primary coolant and of operation of the cooling system.

The large volume of sodium in the primary system provides a reliable source of constant temperature coolant to the reactor. Inlet sodium is pumped from the bulk sodium directly to the reactor. Because of the large heat capacity of the primary sodium, the temperature of the sodium entering the reactor remains essentially constant irrespective of changes in reactor power or reactor coolant outlet temperature or of temperature changes in the secondary system or steam system.

Shutdown cooling of the reactor is accomplished by natural convection of the primary sodium through the reactor. The relative elevation of the reactor and heat exchanger provides natural convection of the coolant even though heat is not removed from the primary sodium in the heat exchanger. If the secondary sodium system is inoperative,

the heat is delivered to the bulk volume of sodium in the primary tank. It is removed by shutdown coolers in the primary sodium, which operate by natural convection and transfer the heat to the atmosphere.

The bulk volume of sodium in the primary tank is also employed as the coolant during reactor unloading. The entire loading and unloading operations are carried out with the subassemblies submerged in the sodium and with the fission product decay heat being removed by natural convection of the sodium. The irradiated subassemblies are permitted to cool in the primary sodium system for 15 days before removal for processing.

The reactor, primary coolant system, and all associated equipment are contained in a building in the form of a gastight cylindrical steel shell designed to withstand a static internal pressure of approximately 25 psig (with a normal safety factor of approximately four). Pressure developed within this container may be the result of energy released in a nuclear accident, energy released in a sodium-air reaction, or a combination of the two. The primary tank structure in conjunction with the biological shield is designed as a primary container to withstand the energy released in a nuclear accident. It is estimated that the structure will easily contain a nuclear accident equivalent to the detonation of 300 lb of TNT in the center of the reactor, and probably could contain an accident several times this large. Although the primary system is expected to contain the nuclear energy release, some primary sodium may be expelled into the building atmosphere. Experimental work described in this report indicates that pressures as high as 80 psig can be obtained under very idealized conditions; such peak pressures, however, being of very short duration. In an accidental expulsion of sodium into the EBR-II reactor building, it does not appear possible that pressures of this magnitude could be developed. It is not expected that pressure due to sodium-oxygen reaction could exceed the static pressure rating of the building shell-25 psig. No water or appreciable quantities of hydrocarbons are employed in the reactor building, thus eliminating possibility of other types of chemical reactions with sodium.

ANL-5721

Walker D E, et al.
BORAX - IV REACTOR: MANUFACTURE OF FUEL AND BLANKET ELEMENTS,
Metallurgy Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill.,
Contract No. W-31-109-Eng-38, March (1958), 75 pp. (4 refs).

This report describes the procedures used in fabricating the core loading for the natural water-cooled Borax-IV reactor. Manufacturing of the fuel plates and blanket plates, which contain fissile (U^{235}) and/or fertile (Th^{232}) material in ceramic form, lead-bonded within tubes in aluminum-1 w/o nickel extrusions, is described in detail. A brief description of the assembly and welding of the finished plates into subassemblies and assemblies is given. Preparation of the ceramic bodies has been described by others in ANL-5669 and ANL-5678.

ANL-5782

Boland J F, Smith R R and Rice R E
A MEASUREMENT OF THE TRANSFER FUNCTION OF A FAST CRITICAL ASSEMBLY,
Idaho Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill.,
Contract No. W-31-109-Eng-38, September (1957), 16 pp. (7 refs).

The zero power transfer function of the ZPR-III mockup assembly of EBR-I, Mark III was obtained over a frequency range from 0.01 to 10 cycles per second. Various oscillator rod materials and shapes were investigated in order to determine the type of oscillator rod that would give the desired amplitude and wave shape for use in future measurements in the EBR-I, Mark III. A null balance was used to obtain the amplitude and phase data to a reasonably high degree of accuracy.

The conclusions drawn from this experiment were that the agreement between the calculated transfer function and the experimental transfer function of the EBR-I, Mark III assembly, obtained with the null balance method, is satisfactory over the frequency range investigated; the detector location does not measurably affect the data over the frequency range investigated; and a steel rod containing an eccentric hold filled with boron is a satisfactory reactivity oscillator for use in a fast reactor.

ANL-5799

Beckjord Eric S
DYNAMIC ANALYSIS OF NATURAL CALCULATION BOILING WATER POWER REACTORS,
Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, March (1958), 29 pp.

Linear Feedback Control Theory is used to analyze the small-signal dynamic behavior of direct cycle, natural circulation boiling water reactor systems.

Transfer functions for thermodynamic and hydraulic effects are derived in terms of reactor core and vessel dimensions. They are used to construct a theoretical system block diagram for the EBWR.

ANL-FWT-105

Brittan R O, et al.
HAZARD EVALUATION REPORT ON THE FAST REACTOR ZERO POWER EXPERIMENT (ZPR-III),
Argonne National Laboratory, P.O. Box 299, Lemont, Ill.,
Contract No. W-31-109-Eng-38, April (1955), 75 pp.

As a part of the program to establish the feasibility of a sodium cooled, unmoderated power breeder reactor (PBR) for the production of economic power, and to facilitate the design, construction, and operation of a prototype reactor, the Experimental Breeder Reactor (EBR-II), Argonne National Laboratory has constructed a critical assembly facility located at the National Reactor Testing Station as a test of the engineering and operational feasibility of PBR. The facility is designed to accommodate experiments investigating the nuclear characteristics of both EBR-II and PBR with either U^{235} or plutonium, or a mixture of both, as fuel materials. The current program covers the use of U^{235} as fuel in studies aimed primarily at the design of EBR-II. This report is an evaluation of the hazards associated with these studies.

Specifically, this report discusses the reactor, building, site, management of the facility, limitation on power level and activation of the core, hazard of accidents, hazard of sabotage, and consequences of accidents.

Two appendices are included. One presents calculations for a severe accident and the other discusses reactivity coefficients.

APAE-2

HAZARDS SUMMARY REPORT FOR THE ARMY PACKAGE POWER REACTOR,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(11-1)-318,
July 27, 1955, 292 pp.

The APPR-1 is described and the various hazards are reviewed. Because of the reactor's location near the nation's Capitol, containment is of the utmost importance. The maximum energy release in any possible accident is 7.4 million BTU's which is completely contained within a 7/8 inch thick steel cylindrical shell with hemispherical ends. The vapor container is 60 feet high and 32 feet in diameter and is lined on the inside with 2 feet of reinforced concrete which provides missile protection and is part of the secondary shield.

All possible nuclear excursions are reviewed and the energy from any of these is insignificant compared to the stored energy in the water.

The maximum credible accident is caused by the reactor running constantly at its maximum power of 10 megawatts and through an extremely unlikely sequence of failures, causing the temperature of the water in the primary and secondary systems to rise to saturation; whereupon a rupture occurs releasing the stored energy of 7.4 million BTU's into the vapor container. If the reactor core melts during the incident, a maximum of 10^8 curies of activity is released.

While it appears impossible for a rupture of the vapor container to occur except by sabotage or bombing, the hazards of the surrounding area discussed in the event of such a rupture occurring simultaneously with the maximum credible accident.

APAE-5 and Suppl.

Meem J L and Noaks J W
HAZARDS SUMMARY REPORT ON THE ZERO POWER EXPERIMENTS FOR THE ARMY PACKAGE POWER REACTOR,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(11-1)-318,
January 27, 1956, 93 pp.

The Zero Power Experiments for the APPR-1 and the Criticality Facility at the Alco Plant in which the experiments will be performed are described. The specific topics discussed relating to this subject are site considerations, experimental program, operation and control, nuclear excursions, accident safeguards, and hazards to surrounding areas.

APAE-8

Noaks J W and Johnson W R
ARMY PACKAGE POWER REACTOR ZERO POWER EXPERIMENTS (ZPE-1),
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(11-1)-318,
February 8, 1957, 133 pp. (5 refs).

This report contains the complete results of the Army Package Power Reactor Zero Power Experiments performed on the APPR-1 core at the Alco Criticality Facility.

The fully loaded cold clean core, containing 22,480.1 grams of U^{235}, has an excess K of approximately 16%. The temperature coefficient at 170°F is approximately $-0.67 \times 10^{-4} \Delta K/^{\circ}F$.

The presence of fine structure in neutron flux measurements and control rod calibrations is evident and further study of these effects from an academic point of view seems justified.

Peak to average flux in the core is as much as 4 to 1 in the tip of the center control rod fuel element. However, flux suppressors placed in the water hole in this region are effective in reducing this value to approximately 3 to 1.

APAE-10 (Vol. I) (Vol. II)

PHASE III DESIGN ANALYSIS FOR THE ARMY PACKAGE POWER REACTOR - VOLUME I. DESIGN ANALYSIS,
Alco Products, Inc., Schenectady, New York, Contract No. AT-(11-1)-318,
August 15, 1956, 266 pp.

The design requirements of the APPR-1 plant are to provide a nuclear power plant location in the United States which will aid in solving technical construction and operating problems associated with a reliable nuclear power plant, provide firm cost data, operating parameters and engineering test data for adaptation to a remotely situated plant; also, to provide a crew training facility.

This report discusses the buildings and grounds; the secondary system which includes heat balance, flow diagrams, turbine gear generator, auxiliary cooling water systems, surface condenser and auxiliaries, circulating water system, feedwater heater and evaporator, and electrical system; the primary system which includes the reactor vessel, pressurizer, steam generator, primary coolant pumps, primary piping, two-way valve and flowmeter, core support structure, fuel elements, control rod assembly, control rod drives, shielding, fuel handling and equipment, and pressure relief devices; reactor analysis; shielding analysis; instrumentation; water treatment; health physics, and waste disposal.

APAE-11

Fairbanks F B
PREDICTED CORE PERFORMANCE FOR THE ARMY PACKAGE POWER REACTOR NO. 1,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(11-1)-318,
August 31, 1956, 100 pp. (18 refs).

The predictions of APPR-1 core performance at zero power and for its operating life are reported, with a description of the methods employed. The window shade model has been used to predict a temperature coefficient of $-0.5 \times 10^{-4} \Delta K/^{\circ}F$ at 68°F and $-3.2 \times 10^{-4} \Delta K/^{\circ}F$ at 450°F. The lifetime based on uniform material burnup is calculated to be 12.1 Mw-yr for a reactor with equilibrium xenon and samarium and 2% available reactivity. If nonuniform burnup effects are considered, the lifetime decreased to 9.1 Mw-yr for the same conditions.

APAE-20

Small W J, Zegger J L and Medin A L
LONG-LIVED CIRCULATING ACTIVITY IN THE ARMY PACKAGE POWER REACTOR,
Alco Products, Inc., Schenectady, N.Y., Contract No. AT-(11-1)-318, August 28, 1957,
33 pp. (5 refs).

Recent experiences at various installations indicated a build-up of long-lived nuclides on primary system surfaces and component parts. In time, this build-up might seriously limit or even restrict accessibility. At present there is no information for systems using a stainless steel core. However, the available data on other systems does indicate that the bulk of the activity can be attributed to the cobalt nuclide. It is conceivable therefore that the use of a stainless steel core may result in activity levels higher than that reported for the zirconium alloys.

This report discusses a program carried out at the Army Package Power Reactor in which the radioactivity in the circulating water was analyzed for long-lived nuclides. Long-lived nuclides resulting from (n - γ) and (n - p) reactions on the clodding and/or structural materials were found. The rate of accumulation and the interrelationship of these nuclides are discussed.

APAE-21

Noaks J W (Editor)
EXTENDED ZERO POWER EXPERIMENTS ON THE ARMY PACKAGE POWER REACTOR-ZPE-2,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(30-3)-278,
November 15, 1957, 203 pp.

Experiments were performed using APPR-1 fuel elements in cores having various diameters, metal-to-water ratios and boron-10 distributions.

The presence of steel in the reflector made a noticeable increase in the core reactivity under certain circumstances.

A relatively simple technique was used to determine the gamma dose rates through shielding materials yielding values in reasonable agreement with theory.

Many gross and fine structure traverses were made with gold, indium and uranium foils including traverses in cores with uniform and nonuniform poison distributions and various control rod configurations. Temperature coefficients of reactivity were nearly identical for various cores from 65^{O} to 130^{O}F.

APAE-25

Medin A L (Editor)
LITERATURE SURVEY FOR ACTIVITY BUILD-UP ON REACTOR PRIMARY SYSTEM COMPONENTS,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(11-1)-318,
January 15, 1958, 79 pp. (35 refs).

A survey has been made of the possible build-up of long-lived radioactivity on primary system components with increased reactor operation. Parameters and mechanisms that may contribute to this activity build-up are discussed.

The activity build-up has been attributed to either deposition and/or atom exchange. Experimental data to date is not sufficient to conclusively attribute the degree to which each of these mechanisms contribute to the build-up. The need for more experimental information, especially for reactors employing stainless steel clad fuel elements, is discussed.

Theoretical equations to predict the extent of the activity build-up are discussed. To-date these equations have not been accurate in predicting the build-up of long-lived nuclides.

Decontamination of primary system components may be required to remove this build-up. A discussion of present-day decontamination agents and their application is discussed.

APAE-29

Brown W S, et al.
CORROSION PRODUCT ACTIVITY IN THE PRIMARY SYSTEM OF THE ARMY PACKAGE REACTOR,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., Contract No. AT-(11-1)-318, April 15, 1958, 70 pp. (3 refs).

Experimental work has been performed to determine the extent and mechanism of the build-up of activated corrosion products in the primary system of the Army Package Power Reactor. This report presents the results of radiochemical analyses of water and crud sampled from the primary system, and of deposits removed from the surface of metal test specimens exposed to the primary coolant. In addition, the dose rates measured during reactor shutdown at the external surfaces of primary system components are reported.

Water, crud, and deposits from the metal test samples were analyzed for long-lived gamma emitting nuclides only. Data are presented on the specific activity of these samples and the nuclide ratios of these specific activities. The build-up of activity on the surface of the metal specimens is shown to be related to time of exposure, temperature of the coolant, and the type of steel specimen used.

APAE-MEMO-85 ASTRA-415-E-2-1

Kroeger H R, Neou I M and Meem J L
THE EFFECT OF GAMMA HEATING ON THE APPR-1 PRESSURE SHELL,
Advanced Scientific Techniques Research Associates, Milford, Conn., Contract No. AT-(11-1)-318, September (1956), 222 pp. (20 refs).

This report is the culmination of several months of detailed study of the problem of thermal stress in a reactor pressure vessel.

For the reactor, thermal shield, pressure vessel configuration of APPR-1, the computed maximum stress in the pressure vessel is 16,820 psi at an operating power of 10 Mw and a pressure of 1400 psig. The thermal stress portion of the above total stress is computed to be not greater than 2640 psi at a point even with the reactor midplane.

This stress is due to a temperature difference in the pressure vessel wall of 13.8°F which results from a computed equivalent energy incident on the cladding of 43,550 BTU/ft^3-hr. This value may be compared to corrected values of 45,500 and 42,400 BTU/ft^3-hr found in tests at the LITR and the MTR, respectively.

The precise computation of energy values for use in thermal stress analysis suffers by general comparison of methods used in shielding. In computing the required thickness of a biological shield, one can make all assumptions conservative without greatly affecting the thickness. For example, if the total dose is overestimated by a factor of 10, the required shield thickness would be only about 20% greater. On the other hand, an overestimate by a factor of 10 in thermal stress analysis might easily indicate a completely nonfeasible design. It is believed that the present computations are somewhat conservative but not overly so.

APAE-MEMO-86 ASTRA-415-E-22

Kroeger H R
THE EFFECT OF GAMMA HEATING ON THE APPR-1 PRESSURE VESSEL - NEW DESIGN, Advanced Scientific Techniques Research Associates, Milford, Conn., Contract No. AT-(11-1)-318, July (1956), 33 pp.

This report examines the effect on pressure vessel stress of reducing the inside diameter of the vessel from the previous specified size (see ASTRA 415E2.1). Although a reduction in diameter decreases the pressure stress, it exposes the vessel to a higher incident gamma energy and the resulting thermal stress increases. As a result, the total stress is relatively insensitive to diameter.

Standard practice for a welded pressure vessel indicates a maximum allowable design stress of 16,600 (for ASTM-A 212-B steel). For a 40.5-inch ID pressure vessel (41 inches ID neglecting the clad) the required wall thickness, based on analyses contained herein, is 2.6 inches. If boron-loaded stainless steel were to be used for the thermal shield, the wall thickness could be reduced to 2.3 inches.

The substitution of a canned lead slab of equal weight, for the present thermal shield, would allow the pressure vessel diameter to be reduced to 39.5 inches. This change in combination with the added efficiency of lead as a thermal shield material reduces the required wall thickness to 2.1 inches.

For the general APPR-1 configuration, the pressure stress represents by far the largest portion of the total vessel stress. The pressure stress can be reduced by increasing the wall thickness, by reducing the vessel diameter, or by lowering the design pressure.

An alternative approach would be to accept a higher pressure stress and specify a steel with a higher allowable design stress.

For reactor vessels, either a reduction in diameter or an increase in wall thickness unfortunately tends to increase the thermal stress.

If the requirement of minimum over-all weight is added to the above considerations, the design of an optimum system becomes somewhat more complex. Several obvious guides can be established:

1. The thermal shield should be positioned as close to the core as is possible without adversely affecting the nuclear characteristics.

2. The thermal shield should be as thin as possible (a heavy shield material) and should be designed to minimize secondary gamma generation.

3. The pressure vessel should be of a high strength steel which still retains favorable properties, i.e., low coefficient of expansion and high thermal conductivity.

4. The clad material for the pressure vessel should be boron-loaded to minimize the generation of gammas (and heat) in the pressure vessel wall.

APAE-MEMO-87 ASTRA-415-E-4-1

Coneybear Frank J, et al.
PUMP FAILURE AND THE APPR-1,
Advanced Scientific Techniques Research Associates, Milford, Conn., Contract No. AT-(11-1)-318, May (1956), 178 pp.

The object of the work described in this report was to find out how soon, after failure of the primary coolant pump, the APPR-1 reactor needed to be scrammed. The reactor was assumed to be operating, initially, at full normal power. The results obtained indicate that the reactor need not be scrammed at all.

This applies for an indefinite period if the amount and pressure of the water on the secondary side of the heat exchanger remain essentially the same as before primary pump failure. It applies, in any case, for times on the order of minutes.

In attaining the results, primary flow momentum and free-convention effects were investigated, as well as the inter-relationship of temperature, reactivity, and power.

APAE-MEMO-89

Oby P V
SCRAM I: CONTROL ROD WORTH CALCULATION ON THE IBM 650,
Alco Products, Inc., P.O. Box 414, Schenectady, N.Y., April 16, 1957, 15 pp.

Scram I is a modified two-group code which determines the gross rod worth of a central cylindrical control rod plus M identical rods in a ring concentric to the central rod. The calculation in this report is applicable only for this rod configuration in a bare cylindrical reactor. The calculations may be used for noncircular rods and reactors provided their properties can be reasonably approximated as equivalent cylinders.

APAE-MEMO-108

Ingeneri Salvatore M
COOLANT FLOW TAILORING PROGRAM OF THE APPR-1 CORE EMPLOYING A FULL SCALE MODEL OF THE REACTOR VESSEL,
Alco Products, Inc., Schenectady, N.Y., Contract No. AT-(11-1)-318, APPR-1, November 15, 1957, 68 pp.

Control of fuel plate surface temperatures in the APPR-1 core is achieved by a non-uniform flow distribution through and between the 38 stationary fuel elements and 7 control rods which comprise the whole core. In order to determine the flow distribution, it was necessary to build a model of the complete reactor to simulate flow characteristics.

The object of this work was to determine the existing flow distribution in the rig core without flow control devices; to regulate, by orificing in the test rig, the coolant flow pattern in the core with respect to fuel elements, control rods, and lattice flow to match the heat flux pattern anticipated in the core; and upon obtaining satisfactory flow distribution within the flow rig, to prescribe the necessary orifice diameters for application in the APPR-1 reactor core.

The results from experimental data obtained from a simulating air flow rig indicate that though the fluid entering the fuel elements and control rods from the plenum chamber follows a rather random behavior, there is, however, a fairly consistent distributional pattern.

ASAE-S-3

Herron D P, Newkirk W H and Puishes A
AN EVALUATION OF HEAVY WATER REACTORS FOR POWER,
American-Standard, Atomic Energy Division, Redwood City, Calif., Contract No. AT-(04-3)-109, October 1, 1957, 73 pp. (refs).

This study was conducted for the US Atomic Energy Commission in the Project Size-Up series. Its purpose was to evaluate heavy water power-producing reactors. Particular attention was paid to the merits of using natural uranium compared with enriched uranium in this reactor type and to the problems of pressure-vessel and equipment design.

Reference designs for pressurized and direct-boiling heavy water reactors were prepared for electrical outputs of 20, 100, and 250 electrical megawatts. A number of possible core designs were considered and those utilized seemed most appropriate to give low-cost power. The technology and costs available today were employed in the preparation of the over-all plant designs. The Consolidated Western Steel Division of US Steel Corporation assisted in this study by preparing a comprehensive report on the design of large pressure vessels and containment vessels. Zirconium-clad metal uranium fuel elements were used as the basis for this study, but the effect of using uranium oxide and stainless-steel cladding was also considered.

APEX-217

Jones L
DESIGN CRITERIA - SHIELD TEST FACILITY,
General Electric Co., Aircraft Nuclear Propulsion Dept., Idaho Test Station, Idaho Falls, Idaho, April 23, 1956, 28 pp.

This report defines the requirements for the construction of a Shield Test Facility (STF) at the Aircraft Nuclear Propulsion Site, National Reactor Testing Station in Idaho. A description of the facility is included which discusses the pool facility and pool facility building, its function, description, services, and equipment; the platform facility, its function, description, and services; the control and equipment building, its function, description, and services; and the area services such as electrical, water, etc.

APEX-228

Cannon C B and Sabo J J
DESIGN CRITERIA IET - EXHAUST FILTER ANP-NRTS,
ANP Dept., General Electric Co., Idaho Test Station, Idaho Falls, Idaho, Dec. 30, 1955, 14 pp.

This document describes the physical features of the Initial Engine Test Facility (IETF) at the Aircraft Nuclear Propulsion Site, National Reactor Testing Station, Idaho. Discussed in this report is the control of design and construction, the operational considerations, the design considerations, and a description of the facilities.

APEX-438

Collins C G and Pomeroy G W
APPLICATIONS AND REQUIREMENTS FOR THERMAL INSULATION IN NUCLEAR REACTORS,
General Electric Co., Atomic Products Div., ANP Dept., Cincinnati 15, Ohio, Contract No. AF33(600)-38062 and AT-(11-1)-171, December 17, 1958, 23 pp. (11 refs).

Applications and requirements are considered in the selection of materials for thermal insulation in a nuclear reactor environment. Important materials criteria include the concentration of neutron absorbers and the stability of the material under bombardment by nuclear particles. The concentration of neutron absorbers should be minimized in insulation materials used in the reactor core or in areas where personnel access is required.

From the standpoint of stability to radiation, organic materials are limited to areas outside the reactor core or its immediate vicinity; inorganic or ceramic materials appear suitable for use in any reactor application. Since some inorganic solids expand during irradiation, fibrous and pellet type of insulation are the most promising for applications inside the reactor or on its surface.

BAC-1

THE BENDIX POOL REACTOR FOR RESEARCH USE,
Presented by Bendix Internation Division of Bendix Aviation Corporation, New York, N.Y.
Prepared by Research Laboratories Division, Bendix Aviation Corporation, Detroit, Mich., January (1956), 45 pp.

This report outlines in some detail a research reactor which the Bendix Aviation Corporation offers for sale under the United States "Atoms for Peace" proposal. The reactor is a modifcation of the one in the Bulk Shielding Facility at ORNL. The design incorporates the essentials for safe and convenient reactor operation plus those features which experience has shown to be desirable in the greatest number of applications. This report gives a general description of the Bendix Pool Reactor and, in detail, describes the reactor core, discusses instrumentation and control, describes the coolant system, gives the general arrangement of the shield, experimental facilities and bridge, and discusses reactor safety.

BAW-1017

Thomas G R
LIQUID METAL FUEL REACTOR EXPERIMENT - PRELIMINARY HAZARDS EVALUATION, The Babcock and Wilcox Company, Atomic Energy Div., Contract No. AT-(30-1)-1940, July (1957), 123 pp.

The Liquid Metal Fuel Reactor Experiment (LMFRE) is designed to provide information necessary for the evaluation of the liquid metal concept and to yield data and experience necessary for the design of large-scale LMFR. This report is an attempt to outline briefly the nature of possible accidents and resulting hazards as well as to describe the design features pertinent to such an analysis.

A section is included which gives a general description of the reactor. This section discusses the reactor core, reflector, reactor vessel, control rods, and test holes. Additional sections are included which discuss the heat removal system, plant layout and maintenance, containment, reactor kinetics, accident analysis, and environmental hazards.

An appendix is included which discusses xenon prompt temperature coefficient, minimum pump coastdown rate, generalized transient analysis, radioactivity release rate, and equation for a cloud due to continuous release from the reactor building.

BMI-1026

Dingee David A, et al.
HEAT TRANSFER FROM PARALLEL RODS IN AXIAL FLOW,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92, August 5, 1955, 50 pp. (4 refs).

This report covers work done at Battelle to investigate the heat-transfer and pressure-drop characteristics of heated rods in axial flow with water as coolant. Three ratios of center-to-center spacing to rod diameters, 1.12, 1.20, and 1.27, in both the square- and triangular-pitch array, were tested at two Prandtl numbers, 1.18 and 1.75, over a range of Reynolds numbers from about 3×10^4 to 6×10^5. The magnitude of the peripheral variation of the heat-transfer coefficient was found to be of the same order of magnitude as the experimental error, which is about 8% of reported values.

The variation of the heat-transfer coefficient down the length of the rod was found to be negligible under the assumption of no transverse mixing of the fluid within an array, which is believed to be the case. The experimental Nusselt numbers fall either on or very close to the equation:

$$Nu = 0.023\, Re^{0.8} Pr^{1/3},$$

depending on the particular geometry of the test model. The square-pitch array showed slightly better heat-transfer characteristics than the triangular pitch. Likewise, the larger spacing-to-diameter ratios showed improved heat-transfer characteristics. These geometric changes varied the heat-transfer properties about 15% from the extremes in the range considered.

Friction factors for all of the test section showed satisfactory agreement with the standard correlation curve for smooth pipes.

BMI-1196

Dayton Russel W
THE EFFECTIVENESS OF CONTROL-ROD MATERIALS,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92, June 24, 1957, 31 pp. (12 refs).

Studies were made of empirical methods for computing the effectiveness of control rod materials. In spite of the incompleteness of available cross-section data, it was possible to correlate measured and computed effectiveness of a number of elemental materials and of dispersions within about 2%. This is approximately the error of measurement. These calculational methods are expected to prove useful in the development of improved control materials by predicting combinations of materials which will posses high control effectiveness.

BMI-1236

Gordon B B, Stone J J, Jr. and Boyd R S
A SIMULATED STUDY OF A REFLECTOR CONTROL SYSTEM FOR A HETEROGENEOUS BOILING REACTOR,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92, November 14, 1957, 14 pp. (5 refs).

A study was made of the feasibility of using a reflector control system for a heterogeneous boiling reactor through use of analog simulation techniques. The reactor kinetics, reactivity, and steam generation were simulated electronically while the hydraulic portion of the reflector system was represented by a full-scale physical mock-up.

The two portions of the system were coupled together, and an attempt was made to achieve a stable, monoscillating system. Various configurations of hydraulic coupling between the reflector tank and surge tank were used in an effort to produce the desired representation of the frictional forces in the system. A system of baffle plates in the coupling produced the desired damping.

With the stable system, the effect of steam-load-demand changes for various values of incremental moderator worth was examined.

These studies showed that a reflector control system for this type of reactor is feasible.

BMI-1240 (Rev)

Hogan William S, et al.
HAZARDS SUMMARY REPORT FOR THE GCRE CRITICAL-ASSEMBLY EXPERIMENTS,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92,
July 22, 1958, 58 pp.

Critical experiments are described and the hazards attendant to these experiments are evaluated for a gas-cooled, water-moderated reactor design.

The proposed reactor has a core 28 in. high and a nominal 2 ft in diameter. The fuel elements will be concentric metal tubes containing UO_2 dispersed in metal. These elements will be located in axial voids through the core. The water moderator and reflector are unpressurized.

The fuel elements for the critical assembly will be uranium foil wrapped on metal tubes located in sealed aluminum cans. These cans are positioned by locating grid plates at the bottom and top of the core.

The reactor design being studied will be controlled by horizontal-acting control blades. A mock-up will be made in the critical assembly of blades of the desired material supported by brackets mounted to the core support structure.

Shutdown control of the critical assembly is achieved by cadmium control blades and by dumping the water into a storage tank. The maximum normal rate of reactivity addition is limited to an estimated 0.04% per sec for all remotely controlled operations. The system is interlocked to ensure that safe operational procedures are followed.

Hazard calculations are made to determine the dosage from direct radiation, fall-out, and inhalation from a radioactive cloud resulting from an accident. The exclusion area is shown to be adequate for even the maximum hypothetical accident.

BMI-1253

Dayton Russell W and Tipton Clyde R, Jr.
PROGRESS RELATING TO CIVILIAN APPLICATIONS DURING JANUARY 1958,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92,
February 2, 1958, 62 pp.

This is a progress report for the month of January 1958, and discusses the following topics:

1. Developments for Zirconium-Clad Fuel Elements
2. Developments for Aluminum-Clad Fuel Elements
3. Plant Assistance to MCW
4. Processing of Feed Materials
5. General Fuel-Element Development
6. Studies of Uranium and Uranium-Alloy Fuels
7. Fatigue Studies of Inconel
8. Reactor Materials and Components
9. Physical Research
10. Corrosion Problems Associated with the Recovery of Spent Reactor Fuel Elements
11. Evaluation of a Reflector-Controlled Heterogeneous Boiling Reactor
12. Studies of Sodium-Tantalum Compatibility at Elevated Temperatures
13. Developmental Studies for the PWR
14. Evaluation of Uranium Monocarbide as a Reactor Fuel

BMI-1258

Orban Alexander R and Hazard Herbert R
STUDIES OF UPPER-PLENUM COOLANT CIRCULATION IN A QUARTER-SCALE AIR-FLOW MODEL OF THE PWR,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92,
March 18, 1958, 42 pp.

Air-flow studies were run in a quarter-scale flow model of the PWR to determine distribution of flow throughout the upper-plenum region with two different hold-down-barrel designs. With each hold-down barrel, flow paths were determined for

operation with four loops, three loops, two opposed loops, and two adjacent loops. Exploration of flow patterns and velocities throughout the upper plenum showed that circulation of coolant throughout the upper plenum was satisfactory with either of the hold-down barrels investigated.

BMI-1290

Bodnar George T, et al.
AN IN-PILE GAS-COOLED LOOP INSTALLED AT THE BATTELLE RESEARCH REACTOR,
Battelle Memorial Institute, Columbus 1, Ohio, Contract No. W-7405-Eng-92,
September 16, 1958, 34 pp.

A developmental program was conducted to provide a loop facility for use in evaluating fuel specimens for gas-cooled-reactor applications. The program included the design, construction, and operation of a recirculating in-pile loop featuring high-pressure gas as the primary coolant. The loop facility was designed for gas pressures of up to 200 psig and gas-flow rates up to 0.415 lb per sec with nitrogen as the coolant. Design features incorporated into the facility included the mounting of the complete "package" on the movable bridge at the Battelle Research Reactor (BRR). This provided ease in moving the loop away from the reactor core for service and specimen transfers.

The loop design featured an aluminum pressure wall and concentric counterflow gas passages with static-gas insulation adjacent to all pressure walls. The entire circulating system was located beneath the water level of the pool to provide shielding and simplicity. The blower was designed for use at 750°F inlet-gas temperature, and it featured both oil and water cooling. The instrumentation was designed to protect personnel and equipment, and to provide information on the specimen during irradiation. The specimen-transfer mechanism was designed to utilize pool-water shielding while moving a dry specimen from the loop cask located approximately 20 ft below the pool surface.

The complete loop system was subjected to both out-of-pile and in-pile evaluation. The blower has operated satisfactorily over 2000 hours, and specimen transfers have been effected without water leakage into the loop or transfer cask.

BMI-ACRS-601 (Rev)

Chastain J E, et al.
HAZARDS SUMMARY REPORT FOR THE BATTELLE RESEARCH REACTOR,
Battelle Memorial Institute, Columbus 1, Ohio, April 4, 1955, 46 pp. (5 refs).

This report is submitted by Battelle Memorial Institute to the Advisory Committee on Reactor Safeguards for their consideration and action concerning the proposed Battelle Research Reactor.

The proposed reactor is a modified "swimming-pool" and will operate at 1000 kw. At this power, it will provide fluxes of fast and slow neutrons and gamma rays sufficient for a variety of experimental applications. After much study, a reactor incorporating an experimental stall attached to a large pool was designed. The reactor can be operated in the stall into which the beam tubes and thermal column converge. The reactor can be operated also in the open pool for shielding studies and large-scale irradiations. The plans for this facility and for the instrumentation, shielding, and controls are described in this report.

Discussions on the make-up of the surrounding area, including climatology, geology, hydrology, seismology, and the distribution of population and industry, are included.

The report further discusses the operating procedure, the fuel inventory required, which is 5103 grams, and the time schedule, which suggests February 15, 1956, as a target date for initial criticality.

The last two sections of the report are devoted to hazards during normal operation and hazards following an accident.

BNL-152

Kaplan I and Chernick J
THE BROOKHAVEN NUCLEAR REACTOR THEORY AND NUCLEAR DESIGN CALCULATIONS,
Brookhaven National Laboratory, Upton, N.Y., Contract No. AT-(30-2)-Gen-16, January (1952), 80 pp. (100 refs).

The theory of normal uranium, graphite-moderated, air-cooled piles is reviewed critically and applied to the design of the Brookhaven nuclear reactor. Calculations of the multiplication factor, critical buckling, critical size, effect of the central gap, excess reactivity, temperature coefficients, xenon poisoning, and control rod effectiveness are discussed in detail. Some other design problems are discussed more briefly. The report is to serve later as a basis for a critical comparison of the theory with the actual behavior of the reactor.

BNL-357(T-65)

Fleck J A, Jr.
THE TEMPERATURE-DEPENDENT KINETICS OF CIRCULATING FUEL REACTORS,
Brookhaven National Laboratory, Upton, N.Y., July (1955), 18 pp. (5 refs).

The kinetic behavior of circulating fuel reactors under conditions of constant inlet temperature can be formulated in terms of partial differential equations in time and displacement along the core axis. By means of a Fourier expansion of the flux, these equations can be reduced to an infinite system of integro-differential equations of "delay" type in the Fourier amplitudes. From the boundedness and nonperiodicity of the solutions to these equations, it is surmised that the oscillations of the system damp. When the flux is approximated by a single Fourier harmonic, the system reduces to a single equation. For small amplitudes of oscillation and for certain values of the parameters, there exist periodic solutions to this equation. Univac solutions of the partial differential equations show that for these parameter values even large amplitude oscillations are weakly damped.

BNL-403 (T-88)

Raseman C J, Susskind H and Waide C H
LMFR-13 LIQUID METAL FUEL REACTOR - IN-PILE FUEL PROCESSING LOOP (LOOP B),
Brookhaven National Laboratory, Upton, N.Y., January (1957), 40 pp. (24 refs).

A molten solution of natural uranium in bismuth at 500°C was circulated through the Brookhaven reactor in a Type 347 stainless-steel system. The uranium-bismuth stream leaving the reactor was equilibrated with helium gas and fused salts to determine

distribution coefficients for certain fission products between metal and salt and metal and gas phases.

The solubility of xenon at 500°C and 1 atmosphere (xenon) was found to be 0.4 ppm and to provide a value of 1.3×10^6 for the Henry's law constant k in the expression $p = kx$. The removal of the xenon by reduction of its partial pressure as a result of the removal of blanket gas at reduced pressure was shown to be within LMER design requirements. More than half the iodine (the xenon precursor) in the loop was found to concentrate on the vessel walls. Other fission products were also studied to determine the degree of deposition on the walls.

Salt contacting experiments were conducted with a LiCl-KCl eutectic and a $MgCl_2$-NaCl-KCl eutectic, and the results agreed favorably with previous small-scale tracer experiments. Indicative of these results are the ranges of the partition coefficients (ppm in salt/ppm in metal) for the following fission products and the $MgCl_2$-KCl-NaCl salt: Cs, 400 to 1020; Ba, 342 to 480; Sr, 125; Ce, 3.17 to 3.82; TRE, 4.07 to 7.55; Zr, 0.03 to 0.14; Ru, 0.9; I, 48 to 235; and Po, 0.73 to 0.76. These are compared to uranium, for separation purposes, with coefficients of 0.03 to 0.06.

The loop was operated continuously in the reactor for 6446 hours, at the end of which shutdown was forced by a heater failure. Leakage was discovered at several points in the system, and it was decided to remove the loop from the reactor.

BNL-433(C-24)-4

Campbell C G and Carter M D
THE EXPERIMENTAL DETERMINATION OF CONVERSION FACTORS,
Atomic Energy Research Establishment, Harwell, Berkshire, England. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 6 pp. (6 refs).

A technique is described for the experimental determination of the initial conversion factor of uranium-fueled systems. Neutron fluxes down to $\sim 10^6$ n/cm^2-sec are sufficient for the measurements. To characterize the rate of Pu^{239} formation, measurements are made of the intensity of the 100-kev Np^{239} x-radiation induced in uranium foils distributed within a fuel element. The rate of destruction of U^{235} by fission is deduced from the activation of fission product catcher foils placed adjacent to U^{238} foils and to foils of the fuel element material. Numerical corrections are made for the rate of U^{235} destruction by neutron capture. The experimental results have been set on an absolute scale by foil irradiations in a thermal flux. The technique provides a simultaneous measurement of the fast fission factor for the system. Results of experiments made in a variety of lattices are presented and compared with calculations.

BNL-433 (C-24)-9

Kouts H and Sher R
EFFECTIVE RESONANCE INTEGRALS FROM EXPONENTIAL EXPERIMENTS,
Brookhaven National Laboratory, Upton, N.Y. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 3 pp.

Bulk experiments on reactor cores at Brookhaven have been found to be consistent with a single choice of n for natural uranium: $n = 1.309 \pm 0.006$. This value has now been used to reinterpret the results of old and new exponential experiments on graphite,

H_2O, and D_2O moderated reactors. The results of the analysis are in each case values of the resonance escape probability and accordingly the effective resonance integrals. These have been analyzed in turn for the separate surface and mass contributions.

BNL-440 (T-89)

Manowitz B, et al.
DESIGN CRITERIA FOR GAMMA IRRADIATION DEVICES USING FLUIDS FLOWING THROUGH REACTOR LOOPS,
Brookhaven National Laboratory, Nuclear Engineering Department, Upton, N.Y., July (1956), 99 pp. (26 refs).

At the request of the Army Reactors Branch, AEC, preliminary design criteria for a food irradiation facility have been prepared. Three possible approaches to the use of a reactor as a source of gamma radiation are discussed: (1) direct use of gammas from fission, (2) use of the fission gases as a source of gamma radiation, and (3) circulation through the reactor of a material that will absorb neutrons and emit gammas some distance away. The third system, the circulating isotope case, was selected as the approach requiring the least engineering development work.

The major problems in the design of a reactor and irradiator are discussed. These include the selection of the isotope to be circulated, the optimization of reactor power and engineering variables to meet the specifications set forth by the Army Reactors Branch, the heat transfer and fluid flow considerations, and finally, the design of the irradiator.

The object of this design is the development of as high a specific activity in the irradiator as possible for the least power. The system should have minimal irradiator and piping holdup and maximal reactor blanket holdup. The flow rate should be high, the parent isotope concentration should be as high as chemically possible. The start-up time, the time for the system to become saturated and reach its maximum specific activity, has also been considered; it is a function of the isotope half life.

The reactor blanket and irradiator volumes have been optimized with regard to reactor power. The system under consideration consists of a reactor surrounded by a blanket through which an isotope solution circulates and then flows through a set of slab irradiators. From the equation that has been developed relating reactor power to specific activity, blanket and irradiator volumes, flow rate, and absorption cross section, a good first approximation to the power required to meet set specifications as to food throughput and dose rate may be found.

The irradiator design, which represents the major portion of this report, has been approached in two ways: (1) what will be the theoretical design to meet the specifications of the Army Reactors Branch and, (2) what will be the required mechanical design of such a facility.

The irradiator has been conceived as two or more parallel slabs between which food packages are made to pass. The approach to the design of the gamma source is in three main stages: (1) the infinite plane source, (2) the infinite slab source, and (3) a bank of parallel infinite cylinders.

The ability of an isotope to maintain a specified ratio between the surface and center doses received by a food package is dependent upon the gamma photon energy of the isotope. Figures are presented illustrating the relation of source thickness, dose rate in food packages, source density, and specific activity.

A conceptual design of the complete food irradiation facility and its auxiliaries has been prepared and is included.

Finally, comparisons were made of the power requirements for both caustic and indium sulfate systems to meet the specifications set forth by the Army Reactors Branch. The power requirements were found to be 35 Mw for a caustic system and 21.4 Mw for an indium sulfate system for the sterilization of 3000 lb/hr of food. Thermal cross sections have been used in all cases, and the possibility of decreasing the power requirement by using the resonance capture of neutrons by indium exists.

BNL-489

PROCEEDINGS OF THE FRENCH-AMERICAN CONFERENCE ON GRAPHITE REACTORS, Brookhaven National Laboratory, Upton, N.Y., 304 pp.

This document contains in most cases the complete papers as presented at the French-American Conference on Graphite Reactors. However, in some instances only the abstracts and references are included. The following is a list of authors and paper titles:

Session I

Primak, W., "The Radiation Damage Dosage"
Hering, H., et al., "Intercomparison of Graphite Irradiations"
Carter, R. L., "An Analysis of Radiation Damage Gradients in Moderator Graphite"
Kernohan, R. H., "The Effect of Fissionable Particle Size on Fission Damage in Graphite"

Session II

Hennig, G. R., "The Slow Neutron Absorption Cross Section of Graphite"
Muehlhause, C. O., "The Slow Neutron Absorption Cross Section of Graphite"
Horowitz, J., et al., "Thermal Flux Flattening and Increase of Reactor Output"

Session III

Primak, W., "Kinetics of Radiation Damaging"
Nightingale, R. E., "Radiation Damage to Graphite from 30° to 150°C"
Mayer, G., et al., "Some Physical Methods for Study of Irradiation Effects in Graphite"
Meyer, R. A., et al., "Effect of Pile Radiation on Mechanical and Other Properties of Graphite"
Powell, R. W., "Control of Radiation Damage in a Graphite Reactor Structure by Annealing"

Session IV

Donahue, D. J., et al., "Determination of K_{∞} from Critical Experiments with the PCTR"

Lanning, D. D., et al., "The Nuclear Parameters of Some Graphite, National Uranium Lattices Measured in the PCTR"
Tanguy, P., "Temperature Coefficient and Neutron Temperature Measurements in G.1"
Zaleski, C. P., "Bucklings and Critical Size Measurements for Various Loadings in G.1"
Hendrie, J. M., "Graphite Temperature Coefficient of the Brookhaven National Laboratory Reactor"
Koechlin, J. C., "French Results on the Natural Uranium - Graphite Lattices"

Session V

Hennig, G. R., "Effects of Radiation and Catalysis on Oxidation of Graphite"
Kosiba, W. L., et al., "The Effect of Radiation on the Rate of Oxidation of Graphite"
Dzurus, M., "Chemical Reactions of Graphite"
Carniglia, S. C., "Interactions of Graphite with Liquid Sodium"
Eichelberger, R. L., "Recent Information on Moderator Sheath Corrosion in Liquid Sodium"
Cunningham, J. E., et al., "Alpha Canning of Uranium Slugs for the ORNL Graphite Reactor"

Session VI

Clayton, E. D., "Buckling Measurements with Enriched Uranium in Graphite Systems"
Richey, C. R., "The Calculation of the Thermal Neutron Flux Distribution in a Unit Lattice Cell - Comparison of Experiment and Theory"
Koechlin, J.C., "Slowing Down of Neutrons from 1.45 ev to Thermal Energy; Diffusion Length and Channel Anisotropy of G. 1 Graphite; Measurements of p and f Factors in G. 1"
Brown, W. W., et al., "Physics Experiments Performed for and on Sodium-Graphite Reactors"
Fillmore, F. L., "Two-Group Neutron Physics Calculations for the Sodium Reactor Experiments"
Bernot, J., "Reactivity Measurements in G.1"

Session VII

Zimmerman, E. L., "A Graphite Moderated Critical Assembly - CA-4"
Kirschbaum, A., "Studies of Enriched Uranium Graphite Reactor Systems"
Byers, C., "Graphite-Moderated, Graphite-Reflected Critical Assemblies"
Hansen, G. E., "Critical Assemblies of Graphite and Enriched Uranium with Beryllium Reflectors"

BNL-2183

Richards P and Rand A C
SOME PIECES OF EQUIPMENT DEVELOPED AT BROOKHAVEN NATIONAL LABORATORY,
Brookhaven National Laboratory, Upton, N.Y., (1954), 14 pp.

A number of small equipment items have been developed by Brookhaven that seem to have some general interest. These items are only briefly described here. They are a small remotely operated bellows valve, a new manual manipulator, a simple air sampler, and a dilution bench.

BNL-2446

REACTOR HEAT TRANSFER INFORMATION MEETING HELD AT BROOKHAVEN NATIONAL LABORATORY, OCTOBER 18-19, 1954,
USAEC and Brookhaven National Laboratory, December (1955), 193 pp.

This document covers the engineering phase of the Reactor Heat Transfer Information Meeting held at BNL.

BNL-3247

THE PRELIMINARY DESIGN OF THE LIQUID METAL FUEL REACTOR EXPERIMENT,
Mechanical Engineering Division, Nuclear Engineering Dept., Brookhaven National Laboratory, Upton, N.Y., April 30, 1956, 136 pp.

The design of the Liquid Fuel Reactor Experiment presented in this report is preliminary. An effort has been made to touch on all the essential parts of a complete plant sufficiently to prepare such data as flow diagrams, layouts, equipment sizes, and the like. These were done with enough completeness to permit realistic cost estimates, but detailed engineering designs were not generally carried out.

The Liquid Metal Fuel Reactor, using uranium in liquid bismuth, offers a wide variety of possible designs. Only one type, the thermal reactor with solution fuel, externally air cooled, is considered in this preliminary design.

BNL-3342

Fleck J A, Jr.
TRANSIENT PRESSURES IN NUCLEAR REACTORS,
Brookhaven National Laboratory, Upton, N.Y., August (1956), 17 pp. (2 refs).

A rigorous examination is made of the transient pressure in an untapered reactor core containing a frictionless compressible coolant. It is found that the maximum pressure is determined primarily by the length of time required for an acoustic signal to travel from the reactor core boundaries to the core center. For a linearly rising temperature it is determined that the maximum transient pressure is quite independent of the amount of fluid in the pipes leading to and from the core. This result disagrees significantly with those obtained on the assumption of an incompressible fluid external to the core. Calculations for a liquid bismuth coolant indicate that excessive transient pressures are unlikely.

BOE-D2-1635 AD-155463

Steele H L
DESCRIPTION OF BOEING COBALT-60 GAMMA FACILITY,
Boeing Airplane Company, Seattle 24, Washington, (1957), 36 pp.

The Physical Research Staff 600 curie cobalt^{60} gamma radiation laboratory is described along with the accessories necessary for its operation. The facility consists of a monitor room, the shielded radiation vault and a ten-foot well of water in the floor of the vault. The cobalt is stored in the well and is raised into the vault by means of a steel

wire and pulley system controlled manually by a winch in the monitor room. A dose rate of 10^6 roentgens per hour is obtained in the region within the ring of the six 100 curie capsules which comprise the 600 curie source. At 1/2 inch from the ring of source capsules, a dose rate of 5×10^5 roentgens per hour is obtained. Since the dose rate must be on the order of milliroentgens per hour in the uncontrolled areas outside the vault, the walls were made of 3-1/2 feet of concrete. The source can be viewed from the monitor room thru a 3-1/2 foot long window of zinc bromide solution. A door interlock and alarm system is provided to prevent access to the unshielded source and to warn of excessive radiation intensities in the monitor room.

The gamma facility is being used to study the effects of gamma radiation on materials, components and systems used in aircraft.

CEND-0005-RS-17

SUMMARY OF PROGRESS IN UNCLASSIFIED AREAS OF REACTOR TECHNOLOGY, Combustion Engineering, Inc., Nuclear Division, Windsor, Conn., February 6, 1958.

One of the major problems in a reactor primary system is that of long lived activity due to cobalt if stainless steel of normal composition is used. In order to minimize this effect, the following materials were considered:

1. Type 304L low cobalt stainless steel
2. 400 series stainless steels
3. Titanium
4. Nonreactor grade zirconium
5. Rhodium-plated stainless steel
6. Alcoa M388 (1% Ni)

Of the above possibilities, it was felt that the use of virgin melts of type 304L stainless steel offered the greatest potential degree of success from both a cobalt and a structural standpoint.

CEP-0056

Axtmann R C, Dessauer Gerhard and Parkinson T G
A SUBCRITICAL PILE FOR RAPID REACTIVITY MEASUREMENTS,
Chemical Engineering Progress - Symposium Series, Vol. 52, No. 19, pp. 165-171, (1956), (2 refs).

Some reactors contain a very large number of identical fuel elements, and each fuel element is usually tested for a number of possible defects before being charged into the reactor. The reactivity of the element is measured in a test pile by period or by control-rod compensation. A disadvantage of this method is that it takes about 15 minutes to measure a period or to determine the critical position of the control rod with sufficient accuracy.

The nuclear test gauge (NTG) eliminates this delay while maintaining the required sensitivity. It is a subcritical pile of small critical mass. A change of reactivity, caused by the replacement of one sample by another, is accompanied by instantaneous readjustment of the neutron multiplication.

The NTG contains a strong neutron source and operates at a multiplication of approximately one hundred. This is high enough for accurate differentiation between acceptable and unacceptable fuel elements and low enough for quick response to changes in successive samples.

Among the design features that are described are a horizontal through-hole that can accommodate a large variety of reactor elements, a safety valve that dumps the light-water moderator within 15 sec, and a difference circuit that plots the reactivity of the test samples on a recorder chart.

CERD-0005-RS-9

Anderson J B
SUMMARY OF PROGRESS IN UNCLASSIFIED AREAS OF REACTOR TECHNOLOGY,
Combustion Engineering, Inc., Reactor Development Division, Windsor, Conn.,
October 18, 1957, 9 pp.

An attempt is made to compute scattered neutron doses for various geometries by single scattering removal cross-section theory. The calculation for slab scattering geometry is compared to an experimentally determined albedo and shows reasonable agreement. An investigation, covering a range of fuel loadings and metal/hydrogen ratios, was carried out for the purpose of testing methods of calculating few group constants currently in vogue in reactor design calculations.

Other topics discussed are cold startup analysis and flux behavior near control rods.

CERD-0005-RS-17

SUMMARY OF PROGRESS IN UNCLASSIFIED AREAS OF REACTOR TECHNOLOGY,
Combustion Engineering, Inc., Nuclear Division, Windsor, Conn., February 6, 1958.

One of the major problems in a reactor primary system is that of long lived activity due to cobalt if stainless steel of normal composition is used. In order to minimize this effect, the following materials were considered:

1. Type 304L low cobalt stainless steel
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Of the above possibilities, it was felt that the use of virgin melts of type 304L stainless steel offered the greatest potential degree of success from both a cobalt and a structural standpoint.

CF-50-2-19

SUPPLEMENT TO PROPOSAL FOR BULK SHIELD TESTING FACILITY,
Oak Ridge National Laboratory, Oak Ridge, Tenn., February 6, 1950, 26 pp.

This memorandum is to supplement the initial proposal for a new bulk shielding testing facility dated December 21, 1949. The topics discussed here are plans for normal reactor operation; reactor safety and control rods circuits; shielding; the kinetic behavior of the reactor; the disposal of water in the pool; and gaseous fission products.

CF-50-4-148

Wilson R H
LITERATURE SURVEY REGARDING BUBBLE FORMATION,
Oak Ridge National Laboratory, Oak Ridge, Tenn., April 27, 1950, 6 pp. (7 refs).

This paper is a review of a number of journal articles pertaining to bubble behavior. The information was reviewed so as to be able to predict bubble behavior in the operating homogeneous reactor. This paper also discusses surface tension and viscosity as well as the laws of solutions of gases in liquids.

CF-50-5-29

Lane J A
FISSION PRODUCT ACTIVITY OF X SLUGS,
Oak Ridge National Laboratory, Central Files, Oak Ridge, Tenn., May 2, 1950, 6 pp.

A knowledge of the energy and intensity of the hard gamma component of the fission product activity at short times after shutdown of the MTR is necessary for designing the shielding of the discharge chute or estimating the required depth of the water in the canal.

In order to determine the attenuation of the fission product activity through water, an entire row of hottest X slugs were pushed from the pile and the radiation intensity measured through seven to eleven feet of water. A table of these measurements is included. Also shown is a plot of intensity 30 minutes after shutdown as a function of depth of water.

CF-51-8-216

Sholl W E, Jr.
ORNL RESEARCH REACTOR DESIGN DATA,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 30, 1951, 32 pp.

The primary purpose of this design data summary is to provide a guide for all engineers actively engaged in the detailed design of the ORNL Research Reactor Project. The information included in this report consists of data which the reactor design group believes should be held fixed wherever possible. Specifically the topics discussed are: reactor structure, reactor controls, reflector, experimental facility design, process water system, nuclear data, and shielding.

CF-51-10-205

Bennett M R
PATENT APPLICATION - 20 PERCENT HNO_3 - 3 PERCENT HF (BY WEIGHT) REAGENT FOR THE DECONTAMINATION OF STAINLESS STEEL,
Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21, 1951, 2 pp.

A reagent mixture of 20% HNO_3 - 3% HF (by wt.) has been found to exhibit extremely effective decontamination properties on both laboratory specimens and Pilot Plant contaminated stainless steel material. Three outstanding observations were made after each decontamination: (1) the corrosion rate was very low (less than 0.1 mil/hr), (2) the metal surfaces were clean and lustrous, and (3) there was no pitting. Decontamination factors of 1000 to 5000 were obtained consistently on laboratory-contaminated samples (5.5 sq in. at 3 x 10^4 cts/min/sq in.) within one hour's time at room temperature, with the solution agitated. Similar decontamination was achieved on stainless steel material contaminated during long-term operation in the Pilot Plant, including a steam jet and a section of stainless steel pipe.

CF-51-11-123

Bennett M R
EVALUATION OF REAGENT DECONTAMINATION - QUARTERLY REPORT FOR PERIOD AUGUST 10, 1951 TO NOVEMBER 10, 1951,
Oak Ridge National Laboratory, Unit Operations Section, Chemical Technology Division, Oak Ridge, Tenn., November 21, 1951, 11 pp.

This report discusses the progress in a program initiated to investigate the decontamination and corrosion properties of various reagent mixtures on welded and nonwelded specimens of Types 309 and 347 stainless steel. A reagent mixture of 20% HNO_3 - 3% HF (by weight) was found to be superior to all other reagents tested in both decontamination and corrosion properties, giving decontamination factors of over 1000, corrosion rates of less than 0.1 mils/hr at 25C, and clean, unpitted surfaces.

CF-52-8-226 (Del)

Wilmer D B, et al.
A PRELIMINARY STUDY OF THE FEASIBILITY OF A GAS-COOLED, GRAPHITE-MODERATED REACTOR FOR POWER PRODUCTION,
Oak Ridge National Laboratory, Oak Ridge, Tenn., August 20, 1952, 120 pp.

The report covers the preliminary design of a helium-cooled, graphite-moderated nuclear reactor and the associated power producing system. The problem is approached with the viewpoint that the system need not represent the economically optimum design, but one which would serve as a pilot plant for future designs. The reactor is designed to operate well within the known limits of safety for the materials of construction, using only those materials which are available at the present time. The fuel is enriched (93.4%) U^{235} in the form of UO_2 inclusions in a stainless steel matrix and with a stainless steel cladding. The reactor is rated at 200 megawatts and the net electrical power output is 55 megawatts. The helium coolant for the reactor transfers its heat to a conventional steam power cycle. The capital cost, including chemical reprocessing and fuel fabrication plants, is estimated to be $39,000,000 and the cost of the electrical energy is 28 mils per kilowatt-hour.

CF-52-10-216

Aven R E, Haubenreich P N and Tobias M
ESTIMATE OF THE EFFECT OF POISONS ON CRITICAL CONCENTRATION,
Oak Ridge National Laboratory, Oak Ridge, Tenn., October 30, 1952, 6 pp.

If a highly-enriched reactor is operated without removal of fission products, poisons will build up so that it is necessary to increase the fuel concentration to maintain criticality at the original operating temperature. Thus the fuel which must be added over a period of time is greater than that burned up by the amount necessary to increase the concentration. To determine the magnitude of this concentration change, calculations have been made for a highly-enriched reactor operating at 50 megawatts. These calculations indicate that after the first year of operation, the necessary U^{235} concentration for criticality is 1.2 times the original concentration, and after five years, about twice the original concentration is required. The exact value for the concentration depends upon the assumed values of poison cross sections.

CF-53-1-283

Feldman M L and Rogers R F
DEVELOPMENT OF DECONTAMINATION REAGENT QUARTERLY REPORT FOR PERIOD NOVEMBER 1, 1952 TO FEBRUARY 1, 1953,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., January 26, 1953, 5 pp. (2 refs).

This development work was the result of a request that a decontamination agent be developed for stainless steel (Type 347) of alkaline or low acid content.

Tables are included which list the results obtained by decontamination with fifteen solution treatments. Another table lists solutions and procedures. Two decontamination procedures appear to be superior to all others tested.

CF-53-3-204

Briggs R B
COOLING REQUIREMENTS FOR THE ORR,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, March 25, 1953, 4 pp.

Calculations indicate that a flow of 2900 gpm through the core and reflector will be sufficient to cool the ORR at an operating power of 5 Mw in a 24-element core. The presently specified 4500 gpm should permit operation at powers as high as 7.3 Mw and possibly 7.5 Mw. It is recommended that the 4500 gpm specification be retained if changes in the water system become necessary to reduce the project cost.

CF-53-10-23

Rickert R J, et al.
A PRELIMINARY DESIGN STUDY OF A 10 MW HOMOGENEOUS BOILING REACTOR POWER PACKAGE FOR USE IN REMOTE LOCATIONS,
Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., August 21, 1953, 150 pp. (41 refs).

This report is based on a study made by its authors while students in the 1952-53 session of ORSORT. It was made and the report prepared in ten weeks.

This report covers the preliminary engineering design of the HBR, a 10 megawatt, homogeneous, boiling reactor package power plant to meet the requirements of service at remote locations such as the arctic bases of our armed forces. Although boiling

reactors have not yet been thoroughly proven experimentally, the results of this investigation place the HBR in a highly competitive position economically, thus providing incentive for the research needed to answer the two remaining questions of nuclear stability and power removal.

The first chapter of the report deals with the over-all concept and the principal points of the design. Chapter II contains the design details of all components. Chapter III discusses the plant operating characteristics and procedures, and Chapter IV, the cost analysis.

The results of this preliminary, hurried study indicate that a boiling reactor has definite possibilities for the power package application.

CF-53-12-119

Cunningham J E
INFORMATION PAPER ON MTR FUEL ELEMENTS,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., December 21, 1953, 11 pp.

Sustained successful operation during the past eighteen months, has completely demonstrated, among the other things, the basic principles which guided the design of MTR fuel elements for service under conditions of high neutron flux. These principles include powering a nuclear reactor with enriched U^{235} fuel, dilution of the fuel in a stable matrix to avoid the dimensional instability problem and use of a plate-type construction to give a higher surface-to-volume ratio for heat transfer purposes.

Although the integrity of the fuel elements was unquestionably proven after experience with the LITR and start-up of the MTR, some development work still remained to be completed in the way of optimizing the design to (1) enhance the nuclear performance of the reactor and (2) reduce the fabrication and chemical processing costs in an effort to produce economics in the over-all operational performance of the reactor. It was felt that any reasonable effort in the direction of increasing the service life or reducing processing costs would certainly be warranted because both the fuel and control elements are replaceable components; hence, contribute a recurring expense.

This report summarizes the important developments contributed by ORNL in behalf of this undertaking. We understand that Phillips Petroleum Company, likewise, is preparing a similar draft outlining their accomplishments.

CF-54-1-81

Halik R R, et al.
U-233 POWER-BREEDER REACTOR - REACTOR DESIGN AND FEASIBILITY PROBLEM,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., January (1954), 263 pp. (55 refs).

The fluidized solids technique, used so extensively in the petroleum and chemical industries, has been investigated for possible adaptation to nuclear power-breeder reactors. This report represents the first attempt to analyze such a system and, surprisingly, shows that the technique is extremely attractive.

The authors have looked at several designs and present detailed engineering and nuclear calculations on the design they consider to have the greatest promise as a breeder-reactor for a large electric power station. Basically, the design calls for the circulation

of solid particles consisting of a fuel-moderator mixture, from the core to a separate heat exchanger vessel from which the solids flow freely to and through the core by gravity. Argon, at essentially atmospheric pressure is recommended as the gas to be used in circulating the solids and fluidizing them in the heat exchanger. The blanket, consisting of solid particles of moderator and fertile material (Th^{232}), is separated from the core region by means of a graphite shell and is fluidized by a separate gas stream.

Many advantages of this system over other existing or proposed systems are listed. Foremost among these are the high breeding gain obtainable, utilization of basic engineering principles presently in use in industry, and the ability to produce steam at pressures and temperatures comparable to those presently available to the power industry.

Nuclear calculations were made using an elaborate 2-group 2-region method. A typical system, operating at 250 Mw (heat output) and producing over 80 Mw electrical power, requiring a 10.5 foot (diameter) core, a 3-foot thick blanket, and 48 Kg of U^{233} in the core proper, is discussed.

Additional holdup of fuel in the heat exchanger and blanket brought the total fuel inventory to somewhat less than 200 Kg. Breeding gains of over +0.2 were calculated even after consideration was given to the poisons, leakage, and core shell absorption.

The authors finally conclude that the fluidized solids reactor appears to be feasible and recommend that additional work be done, especially,

1. In obtaining pertinent experimental data,
2. In making a detailed cost analysis,
3. In investigating the nuclear aspects of this system.

CF-54-6-180

Visner Sidney
A TWO-REGION HOMOGENEOUS REACTOR WITHOUT A CORE TANK,
Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn., June 23, 1954, 7 pp.

It has been recognized that for the economic production of U^{233} and power in reactors up to 15 ft in diameter, the two-region reactor with fuel in the core and fertile material in the blanket is preferable to the single region reactor where all the material is intimately mixed. The advantage of the two-region machine arises from the lower fuel inventory and higher neutron economy if the core shell is sufficiently thin. Also, the effect on reactivity is less pronounced when the slurry settles if it is confined to the outer region.

A design concept is proposed for an essentially two-region reactor--fuel solution in the center and a slurry of fertile material near the periphery--without the use of an intervening core shell. Essentially, by the use of a rotational flow pattern, the reactor vessel is operated as a centrifugal type separator. Although some fuel will be present in the outer region, and although the density distribution of the slurry may not be as distinct as when a shell is present, the effects are probably not important. Several modifications of this principal are considered.

CF-54-8-102

Cochran R G, Henry K M and Flynn J D
OAK RIDGE RESEARCH REACTOR SHADOW SHIELD EXPERIMENTS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., August 31, 1954, 11 pp.

An experiment was performed at the Bulk Shielding Facility to provide additional data on which to base the design of the Oak Ridge Research Reactor. A simple mockup of the proposed ORR shadow shield was installed in the pool and gamma radiation measurements were made behind it.

This report describes the experimental setup and presents data on the scattering effects and attenuation of gamma rays as a result of the lead slab shadow shield.

CF-54-8-237

Rosen M A, et al.
A TEN MEGAWATT BOILING HETEROGENEOUS PACKAGE POWER REACTOR,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., August (1954), 234 pp. (10 refs).

This design study describes a reactor and associated power plant designed to produce 1050 kw of net electric power and 3535 kw of steam for heating purposes. The total thermal output of the reactor is 10,000 kw. The fuel plates consist of highly enriched UO_2 imbedded in a matrix of stainless steel and clad on all sides with stainless steel. The core is cooled and moderated by naturally circulated, boiling, light water. At full power the core has an average void fraction of 20% by volume in the coolant. The saturated steam, at 415 psia and 448.2^{o}F, is used to drive a turbogenerator. This steam is also used to generate nonradioactive steam for space heating.

The reactor is loaded with 18.1 kg of U^{235} and will supply 15 megawatt-years of energy before refueling if required. This corresponds to 2.5 years of operation at an average load factor of 60%. Burnout poison in the form of B_4C is incorporated to reduce the reactivity excursion and thus facilitate control.

The major objective has been to design a reactor which will require a minimum of development effort and yet be reliable and inexpensive. The estimated capital investment is $1,258,400. The estimated cost per kilowatt-hour for net electric and steam power at the bus, based on a 60% load demand is 4.43 cents and 1.08 cents, respectively.

CF-54-8-239

Thomas R A, et al.
ULTIMATE HOMOGENEOUS REACTOR-REACTOR DESIGN AND FEASIBILITY PROBLEM,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., August (1954), 227 pp.

The purpose of this study was to investigate the ultimate limitations of aqueous homogeneous reactor technology. Both the Project Dynamo and the five-year plan report of the Joint Congressional Committee have given to the aqueous homogeneous system the distinction of having the greatest ultimate development potentiality. This study was undertaken to try to assess, by means of a concrete design example, just how far the homogeneous line of development could be pushed.

The first phase of selecting the reactor type for the Ultimate Homogeneous Reactor is discussed. The second phase of the work is presented as a preliminary design of a 200-Mw two-region breeder reactor. Uranyl sulfate solution was selected for the UHR core fluid which is used to generate turbine steam. A boiling D_2O-ThO_2 slurry was used for the blanket. The D_2O blanket steam superheats and reheats the turbine steam.

Pertinent features of the UHR are: (1) higher core power density; (2) higher thermal efficiency; (3) constant turbine steam conditions from no load to full load.

CF-54-8-240

Zeitlin H R, et al.
BOILING HOMOGENEOUS REACTOR FOR POWER AND U^{233} PRODUCTION,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., August (1954), 172 pp.

A preliminary design of a 500 Mw, one region, boiling homogeneous breeder reactor fueled with a slurry of $ThO_2 \cdot UO_2$ in D_2O operating at 1000 psia, has been developed for central-station power. The reactor is of the natural circulating type employing internal liquid vapor cyclone separators and an internal downcomer, and requires no pump or major mechanical devices in the primary loop.

It has been the objective of this study to analyze the problems of control and power removal, to determine what limits the engineering and economic feasibility of such a system, and finally to develop a preliminary design for a typical boiling reactor system.

CF-54-10-176

Kinney W E
STAINLESS STEEL UNIVERSITY REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., October 30, 1954, 8 pp.

This paper presents the results of a study to determine the critical mass of a swimming pool type reactor with stainless steel substituted for aluminum in the fuel plates. The heat transfer in such a reactor is discussed and data presented.

CF-55-4-24

Sanders J P
DEFORMATION OF MTR FUEL ELEMENT IN STATIC PRESSURE TESTS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., April 22, 1955, 36 pp.

Internal pressure tests were made to determine the deflections incurred in the outer fuel plates of MTR elements as a result of internal pressure. It was found that an internal pressure of 7 psi produced a 20-mil deflection in the outer concave fuel plate of an element with 50-mil thick outer fuel plates and 1/8-inch thick side plates.

An investigation of the effect of increasing the thickness of the outer fuel plates in this element indicated that the internal pressure necessary to produce the 20-mil deflection did not change for an element with 60-mil thick outer plates, but changed to 9 psi for a thickness of 65 mils, and 10 psi for a thickness of 75 mils.

Examination of the fuel elements thus tested indicated that the side plates were bending outward near their junction with the concave outer fuel plates thus allowing this outer fuel plate to deform more easily. This fact was confirmed by restricting the bending in the side plate of an element with 60-mil thick outer plates and 1/8 inch thick side plates and comparing the results with an identical unsupported element. The resultant internal pressures necessary to cause a 20-mil deflection were 7 psi for the unsupported element and 15 psi for the supported element.

Increasing the side plate thickness also had a marked effect on the resistance of the outer fuel plates to deformation. An element with 3/16-inch thick side plates and 75-mil thick outer fuel plates sustained an internal pressure of 17 psi with only 20-mils deflection in the concave fuel plate.

Tests in which a vacuum was drawn on the interior of the fuel elements indicated that the convex outer fuel plate was more resistant to deformation by an external pressure than was the concave outer fuel plate. For elements with 60-mil thick outer fuel plates and 1/8-inch thick side plates, an external pressure of 12 psi produced deflections of less than 5 mils in the outer convex fuel plate and deflections of 12 mils in the outer concave fuel plates.

CF-55-5-62

Sanders J P
EXPERIMENTAL DETERMINATION OF FLOW THROUGH HOLES IN SIMULATED MTR END BOXES,
Oak Ridge National Laboratory, Oak Ridge, Tenn., May 5, 1955, 30 pp.

Holes have been cut in the lower end boxes of MTR fuel elements in order to redistribute the flow between the end box and the channels surrounding the end box. A lucite model has been made to simulate these flow channels, and a correlation has been made between the flow through holes connecting these channels and pressure differentials between the channels.

The flow rate in each of the channels was calibrated as a function of a measurable pressure differential. After calibration the flow through holes interconnecting the channels was determined at various combinations of pressure and velocity differences in the channels.

The average static pressure in the system did not influence the flow through the 1/2-in.-diameter holes; however, increased velocity in either the channel representing the flow inside the end box or the channel representing the flow outside the end box caused a decrease in the amount of water transferred through the hole for any given pressure drop. Velocity increases in the smaller channel representing the flow between end boxes had a greater effect in this respect.

CF-55-5-103 (Rev 2)

Green Francis P
A BIBLIOGRAPHIC FILE OF TECHNICAL REPORT ABSTRACTS USEFUL TO REACTOR CONTROL SYSTEM ENGINEERING,
Oak Ridge National Laboratory, Oak Ridge, Tenn., March 1, 1958, 17 pp.

This report describes a punched-card abstract file in use at Oak Ridge National Laboratory. This file consists of three principle divisions which are: (1) reactor control philosophy; (2) reactor types; and (3) an arbitrary grouping of the principle building blocks of the feedback control loop, the reactor lattice control elements, the control actuators, the control computers, and the sensory instruments. Appendix IV consists of a listing of organizations and their report code numbers.

CF-55-6-148

Johnson E B and Henry K M
CRITICAL TESTS FOR THE PENNSYLVANIA STATE UNIVERSITY REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., June 30, 1955, 6 pp.

Critical tests with the fuel elements for the Pennsylvania State University Reactor were performed in the grid of the ORNL Bulk Shielding Reactor (BSR) June 6 and 7, 1955. A total of three configurations were assembled, each of which was completely reflected by water. In each loading the proposed positions of the four control rod elements were simulated.

CF-55-8-175

Nelson M L and Lansing N F
ORR REACTOR PHYSICS: PROBLEM I, INFINITE SLAB MODEL,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 31, 1955, 17 pp. (6 refs).

This report describes the physical system of the ORNL Research Reactor (ORR) and compares it with the chain-reacting core of the Materials Testing Reactor (MTR).

A description is also given of an idealized system which was a primary objective of the initial calculation to obtain a rough idea of the neutron flux distribution.

CF-55-8-190 (Rev)

Guernsey E O, et al.
A FOOD STERILIZATION REACTOR - REACTOR DESIGN AND FEASIBILITY PROBLEM,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., April (1953), 153 pp.

A study has been made to determine the feasibility of sterilizing beef with reactor produced gamma radiation.

Results of the study have been measured against specifications established by the US Army Quartermaster Corps and against estimated results for meat sterilization with other sources of radiation. A conceptual design for a reactor - irradiation system, involving activation of a medium in the blanket of a heterogeneous reactor, satisfies these specifications. It compares favorably with other sources of radiation.

Further work to improve the reactor - irradiation system is recommended.

CF-55-10-99

Johnson E B, Henry K M and Flynn J D
THE WADC VOID MOCKUP TEST AT THE BULK SHIELDING FACILITY,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., October 20, 1955, 19 pp.

A mockup of one of the voids for the proposed WADC reactor was used at the BSR to determine the changes in reactivity which could occur due to the varying of conditions in the void. The void was of sufficient size to completely cover one face of the BSR. Neutron-absorbing curtains (cadmium and boral) were tested to determine their effectiveness in insulating the reactor reactivity-wise from changes inside the void. Equipment to be placed in the WADC void were simulated in the BSR tests by iron slabs located between the neutron-absorbing curtain and the void. The largest reactivity change observed was approximately 3%.

CF-56-4-51

Ullmann J W and Arnold E D
DECAY AND STORAGE OF IRRADIATED FUEL,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., April 9, 1956, 19 pp. (3 refs).

Reasons for storage to allow decay of irradiated fuel elements and possible methods of storage are given. The effects on storage and inventory costs of fuel element composition, plant size, element geometry, reactor type, methods of irradiation and recycle, and type of metallurgical handling are discussed. Estimates and comparisons are included for the decay for several typical fuels. The special problems associated with thorium fuel elements are considered.

CF-56-5-186

Wright W L
THE ORR REACTOR BUILDING, REACTOR STRUCTURE AND SERVICES,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., April 19, 1956, 54 pp.

This report was prepared as the first step in collecting material for an overall report on the ORR Project. The topics discussed here are construction details of the research reactor building and building utilities. Illustrations are included of the ORNL Research Reactor, floor plans, and building sectionals.

CF-56-7-126

Briggs R B and Kolb J O
A HOMOGENEOUS-REACTOR GAMMA IRRADIATION FACILITY,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, July 27, 1956, 15 pp. (6 refs).

This report is the result of a brief study made of a meat-irradiation facility consisting of an aqueous homogeneous reactor and a source utilizing fission-product gases and their daughter products. It was estimated that a reactor power level of 15 Mw would be required to obtain a source that would irradiate 6 in. x 16 in. x 20 in. boxes of meat to a dose of 2×10^6 rep in 30 min and at a rate of 2800 lb/hr. Approximately 1/4% of

the reactor power would be emitted as energy of gamma photons in the source. Based on experience with the Homogeneous Reactor Test, it is believed that the entire facility would cost about $5.5 million.

CF-56-8-203

Brown R A, et al.
A LOW COST PHYSICS AND ENGINEERING TRAINING REACTOR,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, P.O. Box P, Oak Ridge, Tenn., August (1956), 194 pp. (7 refs).

This is a summary report of the efforts of eight students toward a problem in reactor design and is the culmination of twelve months of study.

This report covers the conceptual design of a low cost training reactor for the instruction of physicists and engineers. It is conceived as an instructional tool for a course such as that given at the Oak Ridge School of Reactor Technology. As envisioned in this report, the reactor is of a modified pool type. It is designed for a maximum power level of one megawatt. This arrangement will accommodate engineering experiments, shielding experiments, and critical experiments as well as being useful as a neutron and gamma source.

CF-57-6-87 (Rev)

Parker G W and Creek G E
EXPERIMENTS ON THE RELEASE OF FISSION PRODUCTS FROM MOLTEN REACTOR FUELS,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., May 11, 1958, 22 pp. (9refs).

Experiments in the controlled melting of irradiated fuel specimens, particularly of the APPR, STR, and MTR types, have confirmed that prolonged heating in air at temperatures in excess of the melting point results in the release of a large portion of the radioactivity. On the other hand, a moderate amount of heating in air or steam sufficient only to melt a specimen results mainly in the partial volatilization of the rare gases; the halogens, iodine and bromine; and the alkali metals, cesium and rubidium. In the presence of air or water vapor, strontium and other fission products are not released.

At trace concentration of fission products, slow melting of the APPR plate at 1525°C in air or steam effected the release of 50 per cent of the rare gases, 33 per cent of the iodine, 9 per cent of the cesium and traces of strontium. After 25 per cent burn-up, the cesium value increased to about 60 per cent. Aluminum alloy of the MTR type, also at trace concentration, upon melting at 700°C released up to 2 per cent of the iodine, 10 per cent of the rare gases, and negligible portions of other fission products. Zirconium alloy of the STR type after 15 per cent burn-up when melted at 1850°C, released up to 95 per cent of the rare gases, 90 per cent of the cesium, 60 per cent of the iodine, and only a trace of strontium.

CF-57-7-92

Edlund M C and Noderer L C
ANALYSIS OF BORAX EXPERIMENTS,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., July 19, 1957, 30 pp.

An analysis of the self-limitation of power excursions by steam production in heterogenerous water-moderated reactors using MTR-type fuel elements seems to give excellent agreement with Borax data on both fuel plate temperature rise and total energy for excursions in which the reactor is initially at saturation temperature. A simple model for steam production is developed from thermodynamic and heat diffusion considerations.

In those cases for which the reactor is substantially subcooled, it appears that for MTR fuel elements, at least, all the water in the coolant channels at the hottest part of the reactor must be heated to saturation temperature before steam is produced.

The theory is used to discuss the safety merits of research reactors which differ in neutron generation time, steam void coefficients and hydrodynamic characteristics.

It is shown that heavy water reactors of the CP-5 type, because of their long neutron lifetime, can safely self-limit power excursions resulting from much larger reactivities than can the light water reactors of the swimming pool type. On the other hand, the response of the two reactor types to equivalent accidents, such as the addition of a given amount of fissionable material, is practically the same.

CF-57-8-4

Box W A, et al.
FEASIBILITY STUDY OF A HOMOGENEOUS FUSED SALT-MOLTEN METAL COOLED-POWER REACTOR SYSTEM,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., August (1957), 200 pp. (51 refs).

The reactor system consists of a homogeneous fused salt reactor coupled to a steam power plant by a molten lead heat transfer system. The primary heat exchange between the fused salt fuel and the lead is done by direct mixing of the salt and lead in a jet pump. There are no mechanical pumps or wall-type heat exchangers in the fused salt fuel system. The salt and lead are separated downstream from the jet pump by a pipeline separator. The thermal energy is then transferred to the steam system by the molten lead through conventional type heat exchangers.

CF-57-8-5

Carter W L, et al.
DESIGN STUDY OF AN ADVANCED TEST REACTOR - REACTOR DESIGN AND FEASIBILITY STUDY,
Oak Ridge National Laboratory, Oak Ridge School of Reactor Technology, Oak Ridge, Tenn., August (1957).

Certain design criteria and limitations have been imposed as boundaries and goals for this particular design study. They are:

a. The reactor is to be used for fuel element tests and fuel element experiments only. Other types of research and electrical power production are not to be considered.

b. Four eight-inch diameter through-pipes are to be provided for testing and experiments.

c. A thermal neutron flux of 1×10^{15} n/cm^2-sec or greater should be delivered to the experiment.

d. The thermal neutron flux available for the experiments should not vary by more than 50% over the experiment region.

e. The reactor power should not be in excess of 500 megawatts.

f. A reasonable core life in excess of seven days is desirable.

g. Use of components requiring extensive development is to be avoided because of the immediate need for the reactor. Only existing technology is to be considered.

This study has been primarily concerned with the core design of a reactor to meet the above requirements. Geometrical considerations have been limited to arrangements that will place experiment tubes in regions of highest thermal flux. This investigation was not extended to a complete design of a reactor facility, but has been directed principally toward providing an experiment zone having the desired nuclear properties. A nominal amount of engineering has been considered to recognize some of the problems associated with the construction of such a reactor and to investigate means of heat dissipation.

No attempt has been made to estimate the cost of a complete facility of this type.

The reactor is a heavily-loaded, fully-enriched U^{235} system containing four 8-inch diameter experiment tubes penetrating the core. The core configuration is two fuel slabs separated by a D_2O moderating region containing the four experiment tubes. A fast neutron reflector of 70 volume percent aluminum and 30 volume percent D_2O comprises the region at the outside of the fuel slabs. Unperturbed thermal neutron fluxes as high as 2.48×10^{15} n/cm^2-sec can be supplied to the experiment region for a core lifetime of greater than 12 days at a total reactor power not exceeding 500 Mw.

CF-57-11-30

Johnson E B
POWER CALIBRATION FOR BSR LOADING 33,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., November 28, 1957,
15 pp. (4 refs).

SBR Loading 33 consists of an essentially 5 by 6 fuel element array completely reflected by water. It was controlled by means of two boron carbide shim-safety rods and a Type 347 stainless steel regulating rod with an 87-mil wall. The critical mass was about 3.4 Kg of U^{235}, with an excess reactivity for the clean cold loading of about 0.6%. The total mass in the initial loading was 3.6 Kg of U^{235}.

Power calibrations were made during the first series of runs at power levels appreciably above 1 watt. Cobalt foils were used as the detector material for the thermal neutron flux determination in the lattice.

A number of neutron flux determinations, using indium foils, were made in water along the reactor north-south centerline. Small gold foils were used in the water near the reactor face (0 to 15.5 cm) in order to determine the shape of the attenuation in this region.

The data taken are presented in four tables.

CF-58-4-14

Adams R E and Browning W E
FISSION GAS HOLDUP TESTS ON HRT CHARCOAL BEDS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., April 2, 1958, 14 pp.

Fission gas (Bryston and xenon isotopes) holdup tests on the HRT charcoal beds under simulated operating conditions have been completed. A radioactive tractor technique developed for use in the laboratory absorption study was utilized in these tests. The efficiency of the charcoal beds, in regard to holdup of fission gases, exceeds design specifications. On the basis of these tests, the charcoal beds should perform satisfactorily with the HRT operating at 10 Mw with a total oxygen flow of 3 liters/min or at 5 Mw with a total oxygen flow of 3.5 liters/min, assuming that the maximum charcoal temperature in the first sections of the bed does not exceed 100°C and that the temperature in the 6 inch diameter section is in the 15° - 20°C range.

CN-1869

Compton A H (Project Director)
PROGRESS REPORT - EQUIPMENT DECONTAMINATION,
Separations Development Division, Clinton Laboratories, August 21, 1944, 18 pp.

This report discusses decontamination of stainless steel and development of water-soluble cell paints. Samples of stainless steel were contaminated and then decontaminated by a method outlined in the report. The decontamination was completed without significant corrosion effects. Solutions of sixteen materials were tested on one inch by one inch panels for use as water-soluble coatings for all walls and equipment pieces. The results of these tests are presented.

CN-2208

Leverett M C (Division Director)
FINAL REPORT - EQUIPMENT DECONTAMINATION PROBLEM ASSIGNMENT NO. 242-X21AS,
Clinton Laboratories, Technical Division, Contract No. A-7405-Eng-39, December (1944), 12 pp.

Stainless-steel test pieces from semiworks and plant process vessels, covering a wide range of contamination, were decontaminated. The decontamination factors (DF's) obtained were all in the range 50-200.

Satisfactory decontamination of certain counting instruments made primarily of brass and mild steel was obtained without excessive attack by brief immersion of the brass and mild steel parts separately in 6N(30 per cent) HNO_3 at 65°C.

Tapoganth-$CaCl_2$ water-soluble paint, with and without the addition of 5% glycerine, was tested on cell surfaces and on small panels in desiccators. It was found that the paint tested was very humidity dependent. The Tapoganth-$CaCl_2$ paint, without glycerine, was satisfactory for high-humidity conditions. The 5% glycerine paint was satisfactory for long periods at low humidities.

CP-2459

Metcalf H E
A BRIEF GENERAL DESCRIPTION OF THE ARGONNE URANIUM-GRAPHITE PILE (CP-2),
Argonne National Laboratory, Metallurgical Project, Lemont, Ill., December 20, 1944, 10 pp.

This report gives a general description of the Argonne uranium-graphite pile (CP-2). Drawings are presented to show only the main features of the pile. Minor variations in the lattice are not indicated, nor are all slots or openings spotted.

CRHP-709

Fraser C D and Ophel I L
THE CHALK RIVER LIQUID DISPOSAL AREA, 1956,
Atomic Energy of Canada Limited, Chalk River Project, Chalk River, Ontario, June 1957,
40 pp. (10 refs).

Five surface pits in the Chalk River Liquid Disposal Area have been used since December 1952 for the disposal of wastes containing fission products. The Liquid Disposal Area is situated on elevated ground with low-lying swampy areas to the east and south. Since November 1955 the surface water of these swamps has been contaminated by the seepage of water containing several radioisotopes. Investigations show that three of the five disposal pits are contributing to this surface contamination. The streams and a lake receiving the drainage from these swamps also show low levels of contamination.

Examination of the contaminated area shows strontium^{90} to be the most important of the radioisotopes present. The amounts of Sr^{90} present in the stream draining the area are not sufficient to raise the stream water to the drinking water tolerance concentration. Present levels of Sr^{90} in the plants and animals of the area do not constitute a hazard to man, and contamination is entirely confined to the Chalk River exclusion area.

CVAC-229T FZA-9-250

Soniat A E
LABORATORY DEVELOPMENT OF REACTOR SIMULATOR,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, February 22, 1954,
44 pp. (4 refs).

An electromechanical reactor simulator has been designed and constructed by the Aerophysics Laboratory. The unit satisfactorily simulates the characteristics of a uranium reactor and has been successfully used to check the control system of one such reactor. This report discusses the theoretical background of the simulator, presents a functional description of the system, describes the circuitry used in the simulator, and discusses operational procedure for the simulator.

CVAC-264R FZR-9-055

Castner S V and Paschal F L
IRRADIATED MATERIALS LABORATORY OPERATIONAL PROCEDURES,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No.
AF33-(038)-2117, October 15, 1954, 33 pp.

The purpose of this report is to provide an operational procedure for the Irradiated Materials Laboratory in order to eliminate or reduce the health hazards which are present when testing irradiated materials.

The major objectives of this procedure are to provide the methods and controls required to:

a. Perform the necessary tests and/or examinations on irradiated materials as soon as possible after irradiation.

b. Prevent the spread of contamination both inside and outside of the laboratory.

c. Lower the effective dose rate to personnel conducting tests.

d. Prepare for emergency maintenance, alterations or general repairs to active components of reactors, etc.

This report is broken down into four major categories:

I. General Procedures
II. System Panels Testing Procedures
III. Reactor Components Modification or Repair Procedures
IV. Health Physics Procedures

CWR-464 (Del)

A CONCEPTUAL DESIGN STUDY OF AN ADVANCED ENGINEERING TEST REACTOR, Curtiss-Wright Corporation, Research Division, Quehanna, Pa., Contract No. AT-(30-3)-275, May 1, 1957, 57 pp.

This report contains a technical description of an Advanced Engineering Test Reactor (ATR) conceptual design containing seven major vertical test loops and approximately forty capsule irradiation locations. The peak flux is approximately 5×10^{15} n/cm^2-sec and the average unperturbed flux is 3.5×10^{15} n/cm^2-sec (both values at 186°F). The usable flux within a water-filled test loop is approximately 2×10^{15} n/cm^2-sec at the center loop and 10^{15} n/cm^2-sec in any of the six surrounding loops. A maximum-to-minimum flux ratio of two is satisfied axially over the center three feet of the core.

The design is based upon cylindrical geometry utilizing solid fuel elements in a heavy water moderated core. A graphite reflector surrounds the core region while a heavy water graphite combination serves as the top and bottom reflector. The over-all dimensions are a seven foot diameter by five foot length core with an eighteen inch reflector. Enclosing the core and reflector is a multilayered stainless steel thermal shield cooled by circulation of the moderator.

The reactor is designed for a five-day fuel burnup cycle using boric acid as a poison dissolved in the heavy water moderator. In-core to out-of-core volume ratios for the heavy water moderator indicate that continuous removal of the acid will be required during operation.

The reactor is mounted within a large pressure vessel which is also cooled by moderator circulation. Access holes are provided in the vessel cover for fuel element replacement. The heavy water moderator acts as a primary coolant and is circulated directly to an external heat exchanger. Light water is to be used as a secondary coolant.

Total power at start-up is 520 Mw and 360 Mw at shutdown. The peak power per tube is 6.2 Mw respectively at start-up and shutdown. The initial critical loading is 33 lbs of fully enriched uranium.

An insulating sleeve composed of a one inch thick ring of Al_2O_3 surrounded by a 1/4 inch thick ring of diatomaceous earth is proposed for location next to the inner wall of the test hole and the associated wall temperatures and stresses are presented.

A preliminary design of external heat exchanger is tabulated in detail.

A brief study of possible sites indicated that the criteria of cold water, electric power, isolation, transportation and waste disposal facilities are the controlling factors in that order of importance. Existing Atomic Energy Commission sites were considered and Hanford, Washington, was chosen as the most desirable for this reactor. If the ATR is not located on a presently occupied AEC site, the northern peninsula of Michigan bordering either Lakes Superior, Michigan or Huron or the Klamath River in California near the Pacific coast are felt to be attractive potential locations.

DP-115

Baker C, Jr., Llewellyn W E and Maloney J P
A SIMPLIFIED SAFETY ROD ACTUATOR,
E. I. duPont de Nemours & Co., Pile Engineering Division, Savannah River Laboratory, Aiken, S.C., Contract No. AT-(07-2)-1, May (1955), 20 pp.

The actuator developed at the Savannah River Laboratory for decelerating a safety rod employs a winch drum assembly that is designed to dissipate the energy of the falling rod during its last few feet of travel by rapidly accelerating the drum. The snubbing is accomplished by permitting the last few turns of the cable to unwind from a spiral groove that is cut in a conical surface on one end of the drum. As the cable unwinds from the spiral groove and approaches the apex of the cone, the downward velocity of the rod approaches zero and the drum is accelerated to a high angular velocity. The cable is anchored to a shaft that serves as the axel of the conical drum. The drum can rotate freely relative to the shaft, thereby permitting the rod to remain in its down position after an emergency drop without the cable being rewound by the rapidly rotating drum.

DP-200

Clark H K and English J C
XENON TABLES,
E. I. duPont de Nemours & Co., Theoretical Physics Division, Savannah River Laboratory, Aiken, S.C., Contract No. AT-(07-2)-1, May (1957), 134 pp.

Tables are presented that may be used to estimate the reactivity transients resulting from xenon poisoning in any thermal reactor that employs U^{235} as the principal fissionable material. The Xe^{135} concentration is given as a function of time in units of xenon absorptions per fission neutron. For enriched reactors, these units approximate closely the reactivity held in xenon. The thermal flux is expressed in units of megawatts from thermal fissions per kg of U^{235}. Table entries are spaced at flux increments of 0.005, 0.01, and 0.02 in the flux ranges 0 to 1.0, 1.0 to 3.0, and 3.0 to 10.0 respectively.

DP-245

Babcock D F (Coordinator)
POWER REACTOR STUDIES QUARTERLY PROGRESS REPORT - MAY, JUNE, AND JULY 1957,
E. I. duPont de Nemours & Co., Savannah River Laboratory, Explosives Dept., Aiken, S.C., Contract No. AT-(07-2)-1, September (1957), 66 pp.

The physics, engineering, and equipment characteristics of six schemes for producing electric power from an atomic reactor that is fueled with natural uranium and moderated with heavy water are tabulated in detail. Six power reactor concepts are summarized. Three are D_2O-cooled pressure-vessel reactors, one is a D_2O-cooled pressure-tube reactor, one is a H_2-cooled pressure-tube reactor, and one is a He-cooled pressure-vessel reactor. A seventh reactor concept, a preliminary design of a CO_2-cooled pressure-tube reactor, is discussed in the text along with the other six. The plants are designed to produce 100 Mw of electric power.

The experimental study of the nuclear properties of different arrangements of natural uranium in heavy water was extended to include oxide-fueled lattices. Preliminary measurements of the bucklings of the UO_2-fueled lattices are summarized. The results show that oxide-fueled lattices may be designed for long fuel-exposure cycles; however, direct substitution of oxide fuel for metal fuel in the same reactor lattice may present some difficulties.

Control systems are described for a D_2O-cooled pressure-vessel reactor that operates with hot moderator. Seven control rod clusters and twelve shim rods are capable of controlling the rather wide range in reactivity to which the reactor is subjected as a result of expansion of the moderator as it comes up to temperature and as a result of long-term reactivity transients. A figure shows a possible method for controlling the reactor during startup and changes in demand. Preliminary analysis of the reactor transients that immediately follow changes in demand show that, if the holdup of light water in the steam boiler is large enough, (a) the reactor may be self-regulating over a fairly sizable range of demand changes, (b) negligible surges occur in reactor power, temperature, and pressure during the period of change, and (c) no movements of control rods are necessary to damp the transients. Control rods are moved only to regulate steam temperature, to start the reactor and shut it down, or to compensate for xenon poisoning and long-term reactivity transients. The analysis of the reactor transients is being extended to include large step changes in demand and in control rod position.

A test to assess the effects of high temperature on a zirconium-clad tube of natural uranium metal which had been irradiated to a maximum exposure of greater than 4500 MwD/T showed that heating to 400 to 450°C for a short time caused an additional average growth of about 0.007 inch in outer diameter. The growth that was due to irradiation at low temperature had previously been determined as approximately 0.007 inch also. The average total diametral growth due to both heating and irradiation amounted to approximately one-half per cent.

E-443/N-14

McCullen J D
REACTIVITY LOSS DUE TO XENON BUILD-UP,
Atomic Energy Research Establishment, Harwell, Berkshire, England, January 21, 1954, 1 graph.

This is a graph which shows the value of $\Delta K/K$ loss due to the buildup of xenon after shut-down of the AERE reactor. This loss is plotted as a function of the number of hours after shut-down to a point where the reactor reaches its steady-state value.

EE-1057

Taylor R M
RADIATION HAZARD CONTROL IN A POWER REACTOR INSTALLATION,
Electrical Engineering, Vol. 76, No. 10, pp. 880-883, October (1957), (1 ref).

This paper discusses operational control problems which are necessary to insure adequate protection from two main types of radiation damage, somatic and genetic, when operating a power reactor installation. The general characteristics and types of radiation are discussed.

To avoid the effects of direct damage to the individual (somatic damage), it is suggested that the lifetime dose to any individual should be less than 200 roentgens and should be received over a long period of time at a rate not in excess of 0.3 roentgen per week.

To reduce genetic damage, it is recommended that the individual exposed should not receive more than 50 roentgens by the age of 30 and not more than an additional 50 roentgens by the age of 40. Population dose should not exceed from 3 to 10 roentgens per generation.

Operational hazards, control of external radiation, and control of radioactive contamination are discussed with respect to the operation of a nuclear reactor.

FZM-760

McWhirter J W, et al.
PULSE RADIATION TESTING REACTOR - PRELIMINARY DESIGN,
Convair, Engineering Department, A Division of General Dynamics Corporation,
Fort Worth, Texas, July 20, 1957, 53 pp. (5 refs).

(Proprietary Information)

FZM-1026

Kattner W T
A PROPOSED SYSTEM FOR PERFORMING IRRADIATION EXPERIMENTS, INCLUDING POST-IRRADIATION TESTING, IN CONTROLLER ENVIRONMENTS,
Paper presented at the 2nd Semi-Annual 125A Radiation Effects Symposium, October 22-23, 1957, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, 22 pp. (5 refs).

This paper describes a system for maintaining important environmental conditions about materials samples throughout an irradiation experiment with a swimming-pool reactor source. Desired temperatures, humidities, and atmospheres are imposed prior to and during post-irradiation and during irradiation testing to allow clear interpretation of the data obtained. Features include ease of maintenance, a low-radiation field for operators, and a method for quickly modifying the neutron/gamma ratio in the radiation chambers.

GE-0757

Jacobson J and Carney K G, Jr.
RESEARCH, TESTING, AND PRODUCTION IN THE SWIMMING POOL REACTOR,
General Electric Co., Atomic Power Equipment Dept., San Jose, Calif., July 31, 1957,
16 pp. and several illustrative drawings.

The swimming pool reactor provides a large variety of experimental facilities to enhance distribution and availability of neutrons and gamma radiation for all uses. In addition, the inherent flexibility of the swimming pool reactor make it an extremely useful and practical all around first reactor for educational, research, and industrial institutions.

This report reviews some of the uses of reactors and combines selected types of experiments with experimental facilities available in a typical swimming pool reactor.

GE-1057

NUCLEAR TESTING FACILITY,
General Electric Co. A proposed study prepared for the US Naval Air Development and Material Center by the Atomic Power Equipment Department, October 21, 1957, 32 pp.

This study will include a survey of facility requirements, an analysis of these requirements to determine the most suitable reactor type, and will result in a scoping design of the reactor and reactor facility.

This proposal covers the approach to the problem, results, schedule and cost, personnel, organization, and facilities.

GEA-6326B

NUCLEAR RESEARCH REACTORS FOR INDUSTRIAL, EDUCATIONAL AND RESEARCH ORGANIZATIONS,
General Electric Company, 11 pp.

This document describes briefly three types of reactors as a part of the GE complete reactor building program: the swimming pool reactor, the heavy water reactor and nuclear test reactor.

A quick summary of the useful characteristics is tabulated.

GEC/AER-0358-1

Ingram D J and Stonehouse B H
THE GEC POWER MANIPULATOR,
GEC, Atomic Energy Review, March (1958), 5 pp.

This article describes a power-operated manipulator which is the mechanical equivalent to a human arm and hand. The specific topics discussed are mechanical construction, electrical drives and connections, control equipment, performance, and adaptability.

41

GER-1054

Benedict Manson
NUCLEAR REACTORS FOR RESEARCH,
Massachusetts Institute of Technology, Cambridge, Mass. Reprinted from Chemical Engineering Progress, February (1955), 15 pp. (56 refs).

This paper is an up-to-date account of the many valuable uses which can be made of nuclear reactors and of the types of reactors which are available. It also discusses briefly how research reactors work, their cost, and their safety problems.

GER-1123

Naydan T T and Machell W G
NUCLEAR TEST REACTOR. LIGHT-WATER AND OIL MODERATED REACTOR,
General Electric Co., Schenectady, N.Y., 19 pp.

The design of a nuclear test reactor (NTR) to provide a source of neutrons and to investigate the detection properties of a reactor is given. The detection properties of a reactor are made use of in adjusting the changes in reactivity when fissionable or poison samples are introduced into the reactor core. Changes in the NTR control rod can be measured with an accuracy of 1%, comparable to a change in reactivity of 5.10^{-5}.

The 30 kw unit will produce a thermal flux of 9.10^{11} n/cm^2-sec and fast flux of $2.25.10^{11}$ n/cm^2-sec.

Some of the uses for this reactor are:

1. Nuclear fuel quality control
2. A standard neutron source
3. Exponential and reactor mock-up experiments
4. Danger coefficient measurements
5. Cross-section investigations
6. Foil calibrations
7. Biological investigations
8. Heat transfer studies
9. Food preservation studies
10. Limited isotope production
11. Malignancy treatment studies

Design, description, safety features and circuitry are described in detail.

GER-1287

Lorraine R G
A REVIEW OF BOILING WATER REACTOR PLANTS FOR ATOMIC POWER GENERATION,
General Electric Co., Schenectady, N.Y., August 8, 1956, 15 pp.

The boiling water reactor has five technical advantages. They are:

1. Low reactor pressure
2. Good thermal efficiency
3. The safety feature of steam voids prevents excessive power excursions
4. A flexible load pattern
5. A self-stabilizing power level

Five other favorable aspects present themselves: the status of technology, its flexibility with conventional fueled plants, similarity with conventional plants and adaptability to large size units are factors which favor inclusion in power generation systems.

A generalized description with flow diagrams and heat balances is given.

GER-1384

Prentice B R
POWER REACTOR SYSTEMS,
General Electric Co., Atomic Power Equipment Department, Schenectady, N.Y., January (1957), 27 pp. (6 refs).

A power reactor system is defined as the combination of materials and equipment necessary to produce commercially useful electricity from nuclear energy. It is pointed out that the basic functions which must be accomplished in a nuclear power reactor system are essentially the same as in a conventional power system.

The choice of any major element in a power reactor system, such as the primary coolant fluid, has far reaching consequences throughout the rest of the system. This paper discusses several systems which are grouped by type of primary coolant fluid.

Several systems using water as the primary coolant are discussed. These are: (1) pressurized water reactor system; (2) pressurized water reactor system (tube type); (3) boiling water reactor system; (4) dual cycle boiling water reactor system; and (5) heavy water reactor system. Systems using gaseous coolants are discussed. Two sodium-cooled systems are listed. These are a sodium graphite reactor system and a sodium-cooled fast breeder reactor system. Liquid-fuel cooled systems are discussed.

The report discusses auxiliary systems. Some of these are fuel handling, coolant cleanup, and plant waste disposal.

HLE-CONF-57-1

HOT LABORATORY FACILITIES,
Papers given at Fifth Hot Laboratories and Equipment Conference, Convention Hall, Phila., Pa., March 14-15, 1957, 383 pp.

This document is a collection of papers presented at the conference as indicated. The entire realm of hot laboratory facilities, from tensile testing to metallographic examination, is covered.

HW-13134

Holeman J M
OPTICAL INSTRUMENTS FOR THE ATOMIC INDUSTRY,
Hanford Works, Optical Section, Instrument Division, Richland, Wash., April 25, 1949, 24 pp.

In this paper the Optical Section of the Instrument Division presents some points of interest obtained from the use of optical equipment at the Hanford Works. No complete description of instruments or theory is given.

The object of all the instruments described in this paper is to permit observation without being seen by the radiation hazard involved. The solution is to design an instrument that will transmit light, but not the unwanted radiation.

The engineering problems encountered in optical instruments are discussed. Viewers discussed are those with water shielding, reflective viewers, periscopes, borescopes, binocular periscopes, and stereoscopic periscopes. An additional section is included on effect of irradiating glass.

HW-21793

Davenport D E, Lynn G L and Pound D C
HANFORD STANDARD PILE,
Hanford Works, Physics Section, Pile Technology Division, Richland, Wash.,
Contract No. W-31-109-Eng-52, July 30, 1951, 27 pp.

The construction and diffusion length measurement of the standard pile erected for the exponential experiments are described. The techniques used for accurate flux measurement are given, and the importance of the potential errors discussed. The steps in the calculation of diffusion length from those measurements using the conventional thermal-source approximation and the fast-source theory are outlined and a comparison made of the diffusion lengths so calculated. It is concluded that generally the fast-source theory is preferable although only in the case a single-source was used rather than two or four matched sources did the diffusion length obtained from thermal-source theory differ appreciably from that obtained by fast-source calculations.

The value of the diffusion length of the graphite in the standard pile was found to be 54.4 ± 0.5 cm when corrected to a graphite density of 1.60 g/cc.

HW-24639

Fox J C
REMOTELY OPERATED IRRADIATION FACILITY,
Hanford Works, Pile Technology Unit, Engineering Dept., Richland, Wash., October 15, 1954, 10 pp. (2 refs).

This report discusses the necessity for a remotely operated means for handling samples in C pile test hole Z. It is pointed out that such an installation would eliminate some of the present awkward handling procedures, and could also permit charging and discharging during pile operation. Consequently sample exposures of any time length would be permitted.

Preliminary study indicates that a satisfactory device for this use may be located in the inner rod room and operated from the outer room of C pile. A discussion of operating requirements for such equipment and a possible general arrangement are presented. This layout, planned for the Z test hole at C pile, could be adapted for other accessible through test holes at present or future piles.

HW-33434 (Rev)

Tippets F E
HEAT TRANSFER ANALYSIS OF INTERNALLY-EXTERNALLY COOLED CYLINDRICAL FUEL ELMENTS FOR NUCLEAR REACTORS,
Hanford Atomic Products Operation, Pile Technology Section, Engineering Dept., Richland, Wash., Contract No. W-31-109-Eng-52, October 15, 1954, 39 pp.

One type of fuel element which is considered for use in nuclear reactors is one which is in the shape of a hollow cylinder and which is cooled by the flow of a coolant through both its inner circular passage and the outer annular passage formed by the element and the enclosing process tube. One of the principle requirements of any fuel element is that it meet certain heat transfer criteria.

When making an analysis of the heat transfer characteristics of an internally-externally cooled element it becomes clear early in the problem that either the location of the maximum temperature in the element or the fraction of the generated heat which goes to either coolant passage must be determined before the analysis can proceed further. Previous methods of analysis usually have either required considerable idealization of the boundary conditions or necessitated a trial-and-error solution for one of the unknowns mentioned above. In view of this it seemed desirable to develop and present in detail a nontrial-and-error method which would be sufficiently general that it would be applicable to most problems of heat transfer in internally-externally cooled elements.

Therefore, this document presents the complete detailed development of a noniterative method of analysis of heat transfer characteristics of internally-externally cooled elements. The resulting equations can be applied as well to problems concerning the various types of single-surface cooled elements, which can be considered as special cases. The basic working equations are summarized and a brief description of typical methods of using them is given.

HW-38876

Kaulitz D C and Minor J E
HIGH PRESSURE LOOP DESIGN FOR STUDIES OF REACTIONS BETWEEN HEATED METALS AND HIGH TEMPERATURE WATER,
Hanford Atomic Products Operation, Pile Metallurgy Unit, Metallurgy Research Subsection, Richland, Wash., Contract No. W-31-109-Eng-52, September 9, 1955, 21 pp.

The feasibility of operating water-cooled reactors at high coolant temperatures and pressures depends in part on the nature of the reactions which may occur upon failure of fuel elements or of structural components.

This report discusses a high pressure facility which has been constructed to study the reactions between high temperature water and metal specimens heated well above water temperature. Location of the reaction chamber in a bypass section cut off from the loop proper by two air-operated valves permits the specimen to be protected by an inert atmosphere while the water is heated. Water temperatures and pressures up to 300^{o}C and 2000 psi and specimen temperatures up to 800^{o}C are utilized.

HW-52457

Freshley M D
PLUTONIUM-ALUMINUM FUEL ELEMENT DEVELOPMENT,
Hanford Atomic Products Operation, Reactor and Fuels Research and Development Operation, Richland, Wash., Contract No. W-31-109-Eng-52, September 18, 1957, 44 pp. (21 refs).

Techniques and facilities for handling plutonium at several laboratories in the United States are described. Hazards involved in the handling of the fissionable and highly toxic material are discussed, and the procedures used to guarantee the safety of laboratory personnel are described.

The tentative aluminum-plutonium phase diagram prepared by Los Alamos for compositions ranging from 50 to 100 atomic per cent aluminum is presented. This system is similar to the aluminum-uranium system; the alloys, however, have a greater tendency to segregate upon casting. A eutectic is formed at 1.7 atomic per cent plutonium, and no solid solubility of plutonium in aluminum is observed.

A brief description of the Plutonium Recycle Program at Hanford and Hanford's experience and future plans with the use of aluminum-plutonium alloys as reactor fuel materials is reported.

Aluminum-plutonium fuel element experience at the Chalk River Project in Canada is also discussed, as well as the fabrication of the "napkin" rings by Los Alamos and Argonne; and the fabrication of MTR type fuel assemblies containing aluminum-plutonium alloys by Los Alamos and the Oak Ridge National Laboratory.

From the limited amount of irradiation experience that has been gained with this fuel material, there has been no indication of the dimensional instability and there have been no indications of unsatisfactory performance caused by reactor irradiation.

Even though the health hazard associated with plutonium makes its handling more difficult, safe and economically feasible solutions to fuel element fabrication problems do exist. Further developments on the utilization of plutonium as a reactor fuel material will increase the world's supply of fissionable material and contribute to the peaceful applications of nuclear energy in the United States and the world.

HW-54128

Healy J W
CALCULATIONS ON ENVIRONMENTAL CONSEQUENCES OF REACTOR ACCIDENTS, Hanford Works, Richland, Wash., Contract No. W-31-109-Eng-52, December 11, 1957, 49 pp. (6 refs).

Calculations of the exposure (time integrated concentration) downwind from the release of one curie from a ground source and a 200 meter high source were performed for emission into a strong inversion, moderate inversion, neutral and unstable conditions with wind speeds of one, five, and ten meters per second. Deposition rates were taken as proportional to the wind velocity and were varied as a function of atmospheric stability, while the inversion cases were evaluated using the recent Hanford expressions. The exposures on the centerline of the cloud and the cloud width are given for a "puff" release. Procedures for estimating the area and distances involved following both a short term and prolonged release are given and illustrated for the emission of 25% of the fission products from 50 Mw reactor into moderate inversion and neutral conditions at a wind speed of five meters per second.

HW-54994

deHalas D R
IRRADIATION OF THE BIPHENYL- ORTHOMETA- TERPHENYL EUTECTIC, Hanford Atomic Products Operation, Reactor and Fuels Research and Development Operation, Richland, Wash., Contract No. W-31-109-Eng-52, February 17, 1958, 14 pp. (6 refs).

The ternary eutectic of 55% ortho-, 20% meta-terphenyl and 25% biphenyl has been irradiated in an in-reactor facility. Some of the physical property changes during irradiation have been measured.

The stability of the two terphenyls and the biphenyl towards radiolytic damage are about equal, and only slightly greater than that measured for monoisopropylbiphenyl in previous experiments.

IDO-2022 (Rev 1)

FEASIBILITY STUDY OPTIMUM NATURAL URANIUM, GAS-COOLED, GRAPHITE MODERATED NUCLEAR POWER PLANT FOR USAEC, IDAHO OPERATIONS OFFICE,
Kaiser Engineering, Oakland, Calif., and Nuclear Products - ERCO, Washington, D.C., Contract No. AT-(10-1)-925, March (1958), 64 pp. and design drawings.

The scope of the work includes a preliminary design and feasibility studies of gas-cooled, graphite moderated, nuclear power plants. More specifically, it includes the following major responsibilities:

a. Title I design of a prototype natural uranium fueled plant. This plant is to have a net electrical output of 40,000 kw or such larger size as necessary to meet the prescribed parameters. It is to be a prototype of the optimum plant (Item b).

b. Feasibility study of a full-scale natural uranium fueled plant optimized for cost of power.

c. Feasibility study of a prototype partially enriched uranium fueled plant, or approximately 40,000 kw net electrical capacity, to be a prototype of the optimum plant (Item d).

d. Feasibility study of a full-scale partially enriched uranium-fueled plant optimized for cost of power.

This report contains a discussion of the feasibility design and cost estimates for a gas cooled, natural uranium, graphite moderated power plant optimized for minimum power cost. The plant, rated at 220 mwe (net electrical), is designed for location on the bank of a river in a section of the United States having an average winter and summer climate. The plant consists primarily of one multipurpose building which houses the reactor plant, turbine generator, warehouses and shop. Other facilities include an office building, river pump house, substation and necessary utilities.

The major topics discussed in this report are basis for optimization of the GCPR, buildings and yard facilities, reactor and auxiliaries, fuel elements, steam power plant, utility systems, and cost estimate and schedule.

IDO-2024 (Rev 1)

FEASIBILITY STUDY - OPTIMUM PARTIALLY ENRICHED URANIUM GAS-COOLED, GRAPHITE MODERATED,
Prepared for USAEC, Idaho Operations Office, Kaiser Engineering, Division of Henry J. Kaiser Co., Oakland, Calif., and Nuclear Products - ERCO, Division of ACF Industries, Wash., D.C., Contract No. AT-(10-1)-925, April 1, 1958, 54 pp. and 22 design drawings.

The scope of work on Contract No. AT-(10-1)-925 includes a preliminary design and feasibility studies of gas-cooled, graphite moderated, nuclear power plants. More specifically, it includes the following major responsibilities:

a. Title I design of a prototype natural uranium-fueled plant. This plant is to have a net electrical output of 40,000 kw or such larger size as necessary to meet the prescribed parameters. It is to be a prototype of the optimum plant (Item b).

b. Feasibility study of a full-scale natural uranium fueled plant optimized for cost of power.

c. Feasibility study of a prototype partially enriched uranium fueled plant, of approximately 40,000 kw net electrical capacity, to be the prototype of the optimum plant (Item d).

d. Feasibility study of a full-scale partially enriched uranium fueled plant optimized for cost of power.

This report contains a discussion of the feasibility study and cost estimated for a gas cooled, partially enriched, uranium graphite moderated power plant optimized for minimum power cost. The plant, rated at 215 mwe (net electrical), is designed for location on the bank of a river in a section of the United States having an average winter and summer climate. The plant consists primarily of one multipurpose building which houses the reactor plant, turbine generator, warehouses, and shop. Other facilities include an office building, river pump house, substation and necessary utilities.

IDO-14379

Huff J B
EFFECTIVENESS OF VARIOUS SOLUTIONS FOR DECONTAMINATING STAINLESS STEEL, LEAD, AND GLASS,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, May 24, 1956, 21 pp. (3 refs).

If a drop of nitric acid solution containing mixed fission products from dissolved uranium fuel elements is allowed to dry on a stainless steel surface, a residue remains which is not completely soluble in nitric acid. The insoluble portion, which may be measured by its radioactivity and is generally called contamination, presents a costly problem in the reclaiming of partially burned uranium fuel.

The problem was studied by drying 1 ml portions of a liquid sample on controlled areas in the centers of metal discs. A contaminated spot as large as a twenty-five cent piece on the center of a silver dollar would roughly represent the proportions of the metal samples used. Watch glasses about as large as a twenty-five cent piece were used for the tests with glass. The activity of the initial counts per minute divided by the final counts per minute is the decontamination factor, and is a measure of the relative effectiveness of the procedure used. In order that the decontamination factors be reasonable and finite, no final counts of less than one were used in their calculations. These data were arranged in the order of diminishing decontamination factors in Tables I, II, and III. The most favorable treatments thus appear at the top of each list.

From these tables it may be observed that some solutions were thousands of times more effective than certain others for removing this particular type of contamination. It is also evident that the same treatment may yield a high decontamination factor for stainless steel and a low one for lead.

It is concluded that separate techniques are generally required for decontaminating the individual metals.

IDO-14386

Fletcher R D and Slansky C M
A MULTICURIE FACILITY FOR HIGH LEVEL CHEMICAL PROCESS RESEARCH,
Phillips Petroleum Co., Chemical Development Section, CPP Technical Branch, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, September 17, 1956, 41 pp.

A multicurie hot cell for high level chemical process research is described. The cell is in operation by Phillips Petroleum Company at the Idaho Chemical Processing Plant of the Atomic Energy Commission. Sixty-inch thick barytes concrete walls provide shielding for 75,000 curies of 1.6 Mev gamma activity. Chemical studies are performed with special remote equipment and a pair of Argonne Model 8 master slave manipulators with direct viewing through five feet of 3.2 density laminated glass windows.

IDO-16036

Holm M W
THE DETERMINATION OF U^{235} BURN-OUT IN FUEL RODS,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, February 2, 1953, 20 pp. (9 refs).

A device has recently been completed which makes it possible to determine the γ activity of a fuel rod as a function of position along the axis of the rod. It is the purpose of this report to discuss the practicality of using such apparatus to determine the burn-out of fissionable material in fuel and shim rods.

IDO-16047

Bright G O and Schroeder F
NEUTRON FLUX DISTRIBUTIONS IN THE MATERIALS TESTING REACTOR,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, February 16, 1953, 149 pp.

A series of neutron flux distribution determinations has been made in the MTR. These include complete three-dimensional maps made inside the reactor tank for the reactor conditions of fresh fuel charge and depleted, poisoned fuel charge. A series of measurements in the horizontal beam facilities is shown.

The data are presented as a series of relative activity curves and as a set of absolute flux maps. Absolute values are considered valid within ±20%.

IDO-16076

Wilson T R, Jr.
GAMMA INTENSITIES IN THE MTR GAMMA IRRADIATION FACILITY,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, March 6, 1953, 14 pp. (4 refs).

Increased interest is continually being shown in the irradiation of materials in high intensity gamma fields. Since irradiated MTR fuel assemblies provide an excellent source of high intensity gamma rays, a gamma irradiation facility containing several MTR fuel assemblies in a rectangular array has been placed in the MTR canal. Preliminary measurements of the intensity of the gamma field in the center of the facility

have been conducted using chemical dosimetry techniques. Although the use of chemical dosimetry has not yet been widely adopted, the experimental work reported by Weiss, Hochanadel, Miller and others indicates reliable radiation dose measurements by this method can be obtained.

Since a source of sufficient strength was not available for calibration of the dosimeters, the accuracy and precision of the measurements are not known. However, the measured values agree closely with the calculated results, and it is felt that the data reported can be safely used for approximating the gamma intensity to be expected in the MTR gamma irradiation facility.

IDO-16077

Byron W J and Webster J W
TEMPERATURE COEFFICIENT OF THE MTR AT 30 MEGAWATTS,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, February 16, 1953, 9 pp.

The temperature coefficient of the MTR has been measured with the reactor operating at full power (30 Mw) by observing the compensating motion of the regulating rod upon lowering the inlet water temperature.

Within the limits of uncertainty of the experiment there seems to be no significant change in the temperature coefficient when the reactor is at full power and the fuel, water, and Be are at different temperatures compared to the "zero" power case where everything is at the same temperature.

IDO-16100

Webster J W
THE LOW CROSS-SECTION FISSION PRODUCT POISONS,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, June 8, 1953, 37 pp.

The purpose of this report is to obtain a better understanding of what constitutes the low cross-section fission product poisons, to investigate their rate of accumulation at different fluxes in the MTR, to see how complete the data are for such poison calculations, and to note those isotopes for which it is important to have further cross-section measurements.

The first section of this report gives the "Data," the second section gives the "Method," the third section discusses the "Accuracy of the Calculations," and the fourth section is one of "General Discussion."

IDO-16105

Forbes S G and Nyer W E
FUEL BURNUP DETERMINATIONS BY GAMMA-RAY SCANNING,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, October 16, 1953, 15 pp.

For accountability purposes, it is desirable to determine the quantity of fuel burned in each fuel assembly during its use in the MTR. Measurement of fission-product

gamma-flux from each assembly is one method of obtaining this information. It is the purpose of this report to discuss the limitations of this method and its reliability. To do so, it will first be desirable to consider, in a very general way, the relationship between detector response and fuel burnout. Some of the generalizations will be removed by application of the method to MTR conditions. It will finally be shown that the method can be used at the MTR and that the limits of error can be calculated or determined experimentally.

IDO-16138

Bright G O
NEUTRON FLUX DISTRIBUTIONS IN THE MATERIALS TESTING REACTOR - PART IV. THE 5 X 5 LOADING,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, November 17, 1953, 65 pp.

Flux distribution measurements have been made in the Materials Testing Reactor with the fuel elements arranged in a symmetrical 5 x 5 loading. Three-dimensional thermal neutron flux distribution maps were made for both clean, cold fuel elements and depleted, poisoned fuel elements.

The data are presented as a series of relative activity curves and as a set of absolute flux maps. A qualitative comparison of the flux distribution is made between 5 x 5 loading and the 3 x 9 north slab loading.

IDO-16161

Leyse C F
EVALUATION OF FUEL LOADINGS AND CYCLE TIMES FOR THE MTR,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, April 6, 1954, 32 pp. (3 refs).

A comparison of MTR fuel fabrication costs for various conditions shows that the effects of shim rod service, fuel plate cladding thickness, reactor core geometry, reactor cycle time, and reactor power on these costs are all reduced by increasing the fuel content per fuel assembly. Although a two-week cycle is generally more economical than a three-week cycle, the impending change from the two-week cycle with 168-gram fuel assemblies to a three-week cycle with 200-gram fuel assemblies should show a saving of 3-4.8 $/MwD (megawatt-day). Supplementary information regarding fuel burnup and the requirements as to number of fuel assemblies is included.

IDO-16180

McMurry H L
METHODS FOR CALCULATING LARGE REACTIVITY CHANGES IN THE MTR,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July 26, 1954, 19 pp. (7 refs).

It was required to compare the reactivity losses due to burnup in early MTR runs with the data on poisoning experiments during start up. Formulas based on perturbation theory seem to give the most systematic means for these comparisons. This report derives the formulas that were ultimately adopted. A comparison of reactivity changes calculated for operation with those for poisoning experiments will be given in a subsequent (classified) report.

IDO-16390

Metcalf D R and Kobold V C
A FOUR-REGION, TWO-GROUP CALCULATION OF SPERT-III CRITICAL SIZE AND FLUX DISTRIBUTION,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July 19, 1957, 7 pp.

Critical size and flux distributions were calculated, using the four-region, two-group model based on the present design of the SPERT III reactor. These calculations were made for the 650°F case. The critical size was determined to be about 27.3 cm. This was an increase of about 8% in critical mass in going from an infinite water reflector to a reflector and thermal shields with significant amounts of stainless steel.

IDO-16189

Francis W C
THE ORGANIC LOOP IN THE MTR GAMMA FACILITY DESIGN AND PRELIMINARY TEST,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, August 11, 1954, 46 pp. (8 refs).

An organic fluid circulating loop has been constructed for installation in the MTR gamma facility. The equipment was designed for circulating selected organic fluids, such as diphenyl, and terphenyl at gamma intensities of 10^7 R/hr, temperatures up to 900°F, and velocities up to 20 ft/sec. The organic loop consists of an irradiation coil, pump, removable test sections, primary heat exchanger, pressurizing tank, liquid sampling tank, and various indicating and recording instruments. A secondary Dowtherm loop contains a pump, primary heat exchanger, secondary heat exchanger, and indicating instruments. Data to be obtained are: temperature; pressure; changes in heat transfer coefficient; flow characteristics, as evidenced by viscosity change, decomposition rate in terms of gas formation, pressure rise, and sample analysis, sludge deposition or corrosion, as determined by "before and after" examinations of heated and unheated surfaces.

Initial operation of the equipment has disclosed serious limitations in pump operation. Packing leaks, galling, and low capacity of the pump necessitate its replacement if design conditions are to be met.

IDO-16208

Webster J W
FLAT VERTICAL POWER DISTRIBUTION FOR THE MTR,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, March 24, 1955, 51 pp. (9 refs).

This report solves the two-group reactor equations for the two cases of flat vertical power distribution and flat vertical distribution of the thermal flux.

A distribution of uranium and burnable poison is determined for the MTR to give flat vertical power at startup and approximately throughout a four-week cycle (without experiments). The corresponding flux distributions are computed.

In MTRL-54-58, plans for a fuel assembly development program at the MTR were proposed. Included in this was a proposal to study the advantages of nonuniform fuel distribution and burnable poisons in the MTR (and MTR-type reactors).

The purposes of the present report are four in number. The first purpose is to determine how much the flux, and the integral of flux over core height, could be increased by attaining a flat vertical power distribution in the MTR. The flat vertical power distribution would be obtained through a nonuniform vertical distribution of uranium and burnable poison. It is assumed for computational purposes that sufficient burnable poison would be used to keep the shim rods completely removed from the reactor (an idealized situation). The second purpose is to determine what the distribution of uranium and burnable poison should be to achieve a flat vertical power distribution at startup as well as at the end of the cycle. The third purpose is to investigate the possibility of using an additional short term burnable poison of necessarily high cross section to offset the loss of reactivity due to the buildup of xenon and samarium. The fourth purpose is to study the conditions under which it would be possible to obtain a flat vertical flux (rather than flat power) distribution. The flat flux situation turns out to be more of theoretical than practical interest.

IDO-16209 (Del)

Huffman J R
MTR TECHNICAL BRANCH QUARTERLY REPORT - THIRD QUARTER, 1954,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, December 21, 1954,
25 pp.

High activity levels have developed in the process water system of the MTR, indicating fission breaks in the fuel assemblies. Examination of the fuel assemblies after use shows blemishes on the outer surface of the outer fuel plates. Not all elements have blemishes nor are there any apparent statistics favoring one position in the reactor. The theory is that high temperature corrosion due to low water flow on the outside of fuel assemblies is the cause. The top and bottom end boxes of several elements were punctured with holes to encourage higher outside flows. This seems to alleviate, but not eliminate, the cause. Work on this is continuing as rapidly as possible.

A more sensitive method for monitoring the process water for fission products has been developed. A side stream of water is passed through cation and anion beds. A gamma-ray scintillation counter views the anion bed. By biasing out all activities below 1 Mev, only the short-lived iodine activities are measured (mainly 6.7-hour I-135). This technique cuts out the high background normally induced in the water and thus gives higher sensitivity. In addition, since it measures only short-lived activities, it records the average rate of production of fission products in the system.

The cross-section work during this period has been aimed at developing techniques for measuring fission cross sections and eta values on the crystal and time-of-flight spectrometers. Preliminary values of the ratio $\sigma f_{238} / \sigma f_{235}$ from 0.035 ev to 0.3 ev have been obtained. In the total cross-section field, preliminary values for Np^{237} were determined.

The activation cross sections of Pa^{233} have been investigated by radiochemical techniques. Large resonance activation integrals have been discovered which greatly affect the value of the cross section.

The studies on graphite damage as a possible fast flux monitor have been terminated. The measurement of C_o spacing changes seems to be in the range most useful in MTR exposures.

IDO-16210

Bartz M H and Burnham J B, Jr.
THE MATERIALS TESTING REACTOR HOT CELL,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July (1954), 19 pp.

This hot cell can handle 10,000 to 20,000 curies of 1.5 to 3.0-Mev gamma activity. Versatile, it can accommodate heavy, bulky equipment or delicate, fragile objects for testing and examinations. The pumice block building housing the cell provides working and storage areas. The cell is built of barytes concrete, the walls being 4 ft thick, lined with 1/4-in. steel surfaced with protective coatings; the interior measure 14 x 6-1/2 x 13 ft high. Three 30 x 36-in. windows and a smaller end window give maximum visibility and afford the same shielding as the walls through use of a 32-in. thickness of zinc bromide solution, 8 in. of high-density glass and nonbrowning glass. A General Mills manipulator, a pair of Argonne master-slaves, and a light crane provide flexible remote handling. The exhaust system removes up to 1700 cfm of air, and a separate system exhausted hooded boxes used to handle volatile or dusty substances. Sliding steel doors 18 in. thick close the 6 x 7-ft rear opening. The cell and building were constructed and equipped with windows and manipulators for a total cost of about $268,000.

IDO-16222 WEB-24-54A

Webster J W
ENGINEERING TEST REACTOR,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, March 18, 1955, 31 pp.

The flux perturbations that would exist in a 6" x 6" and a 9" x 9" experimental facility in the ETR have been investigated for various mixtures of Be, Na, U^{235}, Fe, and Be in the hole. The data are presented in the form of plots of thermal flux at the center of the facility versus volume percent moderator, uranium concentration, and poison concentration. The results indicate that the depressed flux relative to the flux outside the hole will not be much less in the 9" x 9" hole than in the 6" x 6" hole for any reasonable composition.

Two core arrays are under consideration: a 10 x 10 array and an 8 x 10 array. It is believed that critical experiments with various core arrays and hole compositions, together with further study of the possibility of shiming with soluble or burnable poison, will be necessary before the best core arrangement can be chosen.

IDO-16228 IDO-16197

Jones R M, et al.
AN ENGINEERING TEST REACTOR FOR THE MTR SITE - A PRELIMINARY STUDY,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, May 23, 1955, 42 pp.

This report presents the results of a one month study of an engineering test reactor to be located at the National Reactor Testing Station, MTR site. General plans are presented for a 75 megawatt light-water-cooled, light-water-moderated, beryllium-reflected reactor in which primary emphasis is placed on relatively large volume high fast neutron flux facilities through the reactor for accommodating loop-type experiments. Benefits of MTR design, construction, and operating experiences have been incorporated to the fullest extent in arriving at a simplified MTR-type reactor which could be designed and built with proven technology and little or no parallel development programs. Additions to the already existing MTR staff for the proposed reactor operation and maintenance would approximate 65 people.

IDO-16259

Conner W P
MTR TECHNICAL BRANCH QUARTERLY REPORT - FOURTH QUARTER (1955),
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, March 12, 1956, 37 pp.

This quarter's contribution to the continuing responsibility of providing technical assistance for the operation and understanding of the MTR has been in several directions. From flux traverse data, it has been estimated that the maximum hot spot for the highest loading at 40 Mw was about seven degrees below the saturation temperature. The delay of fission product gases from their source in the reactor to their exit to the stack was found to be 6.1 minutes by using the radioactive decay of the isotopes as an internal clock. A prototype analog computor offers promise toward simplifying the computation of each fuel loading. The program for the development of improved fuel assemblies shows significant acceleration.

In reactor physics calculations, headway has been made in reactor kinetics by the development of pertinent equations to describe the shutdown mechanism in SPERT-type experiments.

In the field of nuclear property measurements, data are reported for eta of U^{235} from 0.05 to 1.5 ev; cross-section curves and parameters are presented for U^{235} from 10 to 100 ev; and a progress report is given on the determination of the decay scheme of 2.7 hour strontium^{82}. New Soller slits which have an angular resolution of about one-half minute of arc are being installed on the crystal spectrometer.

As part of the improvement of the facilities associated with the MTR, the hot cell capabilities have been broadened by the installation of a remotely operated profilometer. Calibration of the reactivity measurement facility has confirmed the predicted difference in sensitivity to fuel and poison. More accurate data is reported for the gamma intensity and heating values from spent MTR fuel elements. Preliminary calculations suggest that an in-pile indium loop may be useful as an alternative gamma source.

In regard to miscellaneous applications of radioactivity, information is being obtained which is essential to the use and production of thulium^{170} as a practical source for radiography. Also, a method has been developed for assaying solutions containing 10^{-5} to 2 mg of uranium^{235}/ml in 1 ml samples by counting the delayed neutrons after irradiation of the solutions in the permanent graphite pneumatic rabbit facilities.

IDO-16278

Petree F L
REMOTE CONTROLLED MILLING MACHINE FOR MTR HOT CELL,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, May 16, 1955, 11 pp.

This paper describes a remote controlled milling machine for use in the shielded volume of the MTR Hot Cell.

IDO-16284

deBoisblane D R
HISTORY AND OPERATING PRACTICES OF THE MTR REACTOR SAFEGUARD COMMITTEE,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, April 20, 1956, 11 pp.

The Reactor Safeguard Committee at the Material Testing Reactor has been functioning for several years. This report describes the history, organization, and operating practices of this group. Case histories of typical MTR experiments handled by this committee are given. As a result of its contact with the broad range of experimental programs handled at the MTR, the committee has become aware of the need for additional data in a number of important fields relating to hazards evaluation.

Suggestions are made for investigations in a number of vital areas such as reactor physics, heat transmission and engineering properties of materials of construction.

IDO-16316

Bentzen F L
SPERT-I INSTRUMENTATION,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, March 15, 1958, 42 pp.

The SPERT-I reactor is used to investigate reactor behavior under simulated accident conditions. The primary data consist of measurements of fuel plate temperature, reactor power and transient pressure as functions of time. Because of the nature of the tests all reactor operation and data recording are performed from a point 3000 ft from the test area. The various problems associated with in-pile detectors, signal handling and operation are discussed. Instrumentation and circuitry for both the transient data system and reactor operation are presented.

IDO-16317

Miller R W
CALCULATIONS OF REACTIVITY BEHAVIOR DURING SPERT-I TRANSIENTS,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, June 1, 1957, 35 pp. (7 refs).

Response of the SPERT-I reactor to stepwise insertions of reactivity has been investigated and previously reported. Using experimental power data from these excursions along with the familiar diffusion approximation kinetic equations, it has been possible

in most cases to calculate the combined time-dependent effect of the shutdown mechanisms on the reactivity of the system during transient response. These data along with transient power and energy release are presented on composite graphs for a number of excursions ranging in period and reactivity insertions from $\tau = 2$ sec and $\Delta k_o = 0.48\%$ to $\tau = 0.007$ sec and $\Delta k_o = 1.4\%$.

From the data calculated in this fashion the amount of reactivity which was compensated at the peak of the first power burst may be observed. These values are dependent upon the transient period as well as other reactor parameters and are presented in graphical form.

Included in the appendices are brief discussions of the numerical solutions of the kinetic equations and the limitations of these equations under this usage.

IDO-16318

Wilson T R
AN ENGINEERING DESCRIPTION OF THE SPERT-I REACTOR FACILITY,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, June 14, 1957, 43 pp. (5 refs).

An engineering description is presented herein of the SPERT-I reactor facility. The SPERT-I reactor is the first of several reactors to be built for the purpose of conducting reactor transient behavior and safety studies on heterogeneous, light-water-moderated, enriched-fuel reactor systems. The reactor consists of an open vessel into which has been placed initially a plate type, uranium-aluminum core with no provision for heat removal or coolant circulation. The reactor is remotely operated from a control center approximately 1/2 mile from the reactor. Reactor excursions are brought about by the rapid addition of reactivity to the reactor, and the resulting kinetic behavior of the reactor observed.

IDO-16322

Rainwater J H
MAINTENANCE OF PRIMARY COOLANT WATER QUALITY IN THE MATERIALS TESTING REACTOR,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, February 21, 1957, 54 pp.

MTR experience with regard to process water quality and radio-activity is presented. It has been found that fission products and uranium plate out on reactor components quite readily, thus creating a continuous source of fission products even though the original source of fission products is removed. Data is also given which shows the effectiveness of using a cation resin bed in removing fission products from the system. Other general information is given on gas production and nitrogen fixation in MTR.

This report is being issued because of the wide demand for information of this type. The report is a direct reprint of material prepared for Chapter III - Maintenance of Coolant for the Reactor Handbook and for this reason is in a format peculiar to this particular chapter.

IDO-16325

McMurry H L
NUCLEAR CALCULATIONS FOR SPERT-III,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, March 25, 1957, 20 pp. (4 refs).

This report gives the results of preliminary critical size and control rod worth calculations for the first SPERT-III core design. This design assumed that adequate control can be obtained by blade-type rods operating in slots similar to the design in SPERT-I. The critical size calculations take account of the effect of this slot. When it was determined that blade-type control rods would probably be inadequate, control rod calculations were made assuming a homogeneous core with fuel-bearing shim rods.

These calculations indicate a critical mass of ~20 kg at 650°F and an excess k of ~20% when loaded to this size at 68°F. Detailed results are given in Tables V I and V II.

While this work was in progress the SPERT-III design was altered to eliminate the blade type rods and the slot accommodating them. Critical size and control rod calculations more pertinent to the actual design will be described in a separate report.

IDO-16341

Wilson T R
THE SPERT-III REACTOR FACILITY PRELIMINARY DESIGN REPORT,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, May 6, 1957, 31 pp. (3 refs).

The SPERT-III reactor is designed for conducting basic transient and reactor safety studies under conditions encountered in high power, heterogeneous, light water reactors. The reactor and primary coolant system are designed for operation up to 2500 psi and 650°F. Coolant flow rates up to 20,000 gpm are provided with heat removal capacity sufficient for 60 Mw for approximately 30 minutes. A description and preliminary design data report of the facility are presented.

IDO-16367

Vance F P
EQUATIONS FOR MTR BURNUP APPORTIONMENT,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, December 3, 1956, 16 pp.

Derivation of a set of equations is described for use in computing percentage burnup of U^{235} in the MTR attributable to each lattice position occupied by a fuel element. It is shown that the use of five equations is adequate to define the 29 percentages, within significant differences. The equations are presented. An extensive table of data is included.

IDO-16368

Van Sice R B (Editor)
HYDRAULIC FLOW CALCULATIONS FOR MTR-ETR EXPERIMENTS STANDARD PRACTICES MANUAL,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, November 1, 1957, 68 pp. (23 refs).

Recognizing the need for uniform methods of making hydraulic calculations, Phillips Petroleum personnel have compiled typical examples of hydraulic flow calculations. These examples and methods of calculation have been reviewed by the Phillips Reactor Safeguard Committee and approved as standard methods to be used in future hydraulic problems pertaining to experimental work at the MTR and ETR.

IDO-16382

Bright G O and Toole C R, Jr.
NOTE ON THE EFFECT ON REACTIVITY OF WATER ANNULI IN LARGE VOID SPACES IN THE SPERT-I REACTOR CORE,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July 1, 1957, 9 pp. (1 ref).

An experiment has been performed in the SPERT-I reactor to determine the effect of various water annuli in large core void spaces. Results show that the maximum reactivity effect with a 3 in. x 3 in. x 24 in. void occurs with a 0.25 in. thick water annulus. The effect of these results on the evaluation of potential reactor hazards is discussed.

IDO-16383

Schroeder F
STABILITY TESTS WITH THE SPERT-I REACTOR,
Phillips Petroleum Company, Atomic Energy Division, Idaho Operations Office, USAEC, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, July 1, 1957, 13 pp.

The existence of unstable behavior in the SPERT-I reactor has been previously reported. Recent tests, in which the conditions for the onset of this instability were investigated, are discussed. Tests were conducted with the initial bulk water temperature at 20°C and 97°C (boiling), and with the initial height of the water head over the core at 2 feet and 9 feet. The reproducibility of all such stability tests is discussed.

IDO-16386

Wilson T R
THE SPERT-II REACTOR FACILITY - PRELIMINARY DESIGN REPORT,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, October 1, 1957, 22 pp.

A summary of the preliminary design features of the SPERT-II reactor facility is presented. The SPERT-II is one of a series of SPERT (Special Power Excursion Reactor Tests) reactors which will be utilized to obtain experimental information on the kinetic behavior of reactors in order to provide additional information to the industry

for the evaluation of reactor hazards. The primary function of the SPERT-II facility is to permit a study of the influence of the prompt neutron lifetime on reactor transient behavior and reactor safety by providing for the use of various moderators and reflectors, especially light and heavy water. The vessel is designed so as to facilitate changes in core types and reflector types and their configurations. The reactor vessel and coolant system are designed for operation at pressures up to 300 psi, temperatures up to 400°F, and coolant flow rates up to 20,000 gpm. Both upward and downward coolant flow through the reactor core is permissible; however, since the facility is intended only as a transient test facility, no heat removal equipment is included.

IDO-16393

Bright G O, et al.
AN ELEMENTARY MODEL FOR REACTOR BURST BEHAVIOR,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, August 2, 1957, 12 pp. (3 refs).

An elementary model for the description of reactor transient behavior is presented. Work initially done by Fuchs and later by Weinberg and Ergen has been extended to include a correlation between transient pressures and the rate of change of power. A modification of the above equations is made to take into account an elementary hydrodynamical consideration. The situation where the shutdown coefficient has an energy release threshold is discussed.

IDO-16394

Evans J E (Editor)
QUARTERLY PROGRESS REPORT FOR MTR TECHNICAL BRANCHES - 2ND QUARTER (1957),
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, August 22, 1957, 64 pp. (22 refs).

This is a progress report from the MTR technical branches and lists work performed by the various groups. The Engineering Test Reactor, ETR, was taken to criticality with twenty-two fuel elements and five control-fuel sections. A detailed study on the calculation of MTR fuel loads is presented and a method for calculating the ETR charge life has been developed. SPERT-I calculations are being modified in the light of experimental measurements. The fission and total cross section of U^{233} has been extensively studied.

IDO-16401

McMurry H L, Cazier G A and Goin R W
CALCULATION OF MTR FUEL CHARGES,
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho,
Contract No. AT-(10-1)-205, September 27, 1957, 32 pp, (9 refs).

For economical operation of the MTR, mixtures of new and used fuel must be scheduled so that the required cycle time is met, and start-up after a scram when Xe^{135} is present in the retained elements, is possible. The procedure described here starts with an equation relating charge life to the amount of uniformly distributed poison needed to keep a freshly loaded reactor just critical with all control rods out. This equation is

adapted to give an expression for the life of a new fuel charge in terms of the known life of the preceding charge, and the changes in the initial fuel loading of the charges. It is then only necessary to compute the difference between the life of the new charge and the preceding one.

Expressions for the distribution of retained fuel, and fuel recycled from the canal which will permit start-up after a scram when Xe^{135} is present in the retained elements, are also developed.

IDO-16404

Deverall L I and Griffing G W
KINETIC STUDIES ON THE SPERT I REACTOR--PART II. ON THE INITIAL SHUTDOWN OF THE SPERT-I REACTOR FOR PERIODS GREATER THAN 50 MILLISECONDS, Phillips Petroleum Company, Idaho Falls, Ida., Contract No. AT-(10-1)-205, December 26, 1957, 17 pp. (6 refs).

For transients of SPERT-I initiated at approximately 20°C and where the reciprocal period is less than 20 sec^{-1}, the plate temperature does not rise sufficiently by the time of maximum power for boiling to have occurred. For this region one inquires whether it is possible that moderator expansion due to thermal effects is sufficient to have shut down the reactor. Using the observed temperature traces of the fuel plates, an estimate of the temperature rise of the moderator can be made at the time of peak power and hence the amount of reactivity compensated. On the other hand, the compensated reactivity is also obtainable from the use of the observed power traces. A comparison of the two values indicates that the computation based on the temperature is lower than the one based on power by a factor of about two. Although this comparison suggests that other mechanisms are needed to explain the self-shutdown of the transients for reciprocal periods less than 20 sec^{-1}, there is the possibility that the discrepancy is not real due to the inherent inaccuracy of the available information.

IDO-16409

Robinson M S
RADIATION DAMAGE STUDIES PROGRAM ETR LOOP MATERIALS PROGRESS REPORT II, Phillips Petroleum Co., Idaho Falls, Ida., Contract No. AT-(10-1)-205, September 16, 1957, 33 pp.

A program has been under way at the MTR to determine changes in mechanical properties with irradiation for special alloys under consideration for use in ETR high pressure loops. Subsize tensile and impact samples are being irradiated in the MTR, and tensile samples irradiated through four cycles have been tested for the following materials: 16-1 Croloy, Hastelloy-X, Inconel-702, Inconel-X (double aged), Inconel-X (single aged), K-Monel, 410 Stainless Steel. Nickel-plated samples of 2-1/4 Croloy corroded too much to permit testing.

All materials, with the exception of 16-1 Croloy, revealed a continual increase in yield strength and a decrease in elongation with irradiation as expected, but the ultimate tensile strength of Inconel-X and K-Monel and both ultimate tensile strength and yield strength of the 16-1 Croloy appeared to decrease with irradiation after reaching a maximum.

IDO-16416

Bright G O
QUARTERLY PROGRESS REPORT--JULY TO SEPTEMBER, 1957,
Phillips Petroleum Co., Reactor Projects Branch, Atomic Energy Division, Idaho Falls, Ida.
Contract No. AT-(10-1)-205, October 1, 1957, 84 pp. (14 refs).

This report is a summary of progress as concerns the SPERT project. A description of the facilities, control, and instrumentation along with theoretical calculations of critical mass are discussed. Phase I, II, and III of the SPERT project are discussed in detail.

IDO-16418

Montgomery C R, Norberg J A and Wilson T R
SUMMARY OF THE SPERT-I, -II, AND -III REACTOR FACILITIES,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Ida., Contract No.
AT-(10-1)-205, November 1, 1957, 34 pp.

This report is a compilation of the engineering, operating, and physics data of the SPERT-I, -II, and -III reactor facilities which have appeared in previously published detailed reports. Each reactor and the auxiliary equipment is briefly described and the design data for the three reactors are summarized.

IDO-16420

McMurry H L
MTR CHARGE LIFE WITH MIXTURES OF U^{235} AND PU^{239},
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Ida.,
Contract No. AT-(10-1)-205, October 23, 1957, 14 pp. (3 refs).

An equation for the cycle time of an MTR fuel charge containing mixtures of U^{235} and Pu^{239} fuels is presented. The role of captures in the resonances at 0.3 ev in Pu^{239} and 1 ev in Pu^{240} is included:

As a by-product, the equations permit estimating the amount of Pu^{239} per fuel assembly needed to give the same cycle time as an arbitrary distribution of U^{235} fuel for which the cycle time is known. It avoids some of the simplifications employed in earlier work on this problem. Once the proper weight factors have been determined, the equations can be solved readily by hand. However, they can easily be programmed for machine solution.

IDO-16426

King D C
HIGH PRESSURE WATER LOOP EXPERIMENTS IN THE MTR,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Ida.,
Contract No. AT-(10-1)-205, November 14, 1957, 24 pp. (2 refs).

A high pressure, high temperature water loop in the MTR is designed to simulate operating conditions of proposed reactors for the purpose of studying the stability of prototype fuel elements. There are presently five operating loops in the MTR with one

being constructed and a seventh now in the design stage. There are also six loops proposed for the ETR.

The high gamma flux in the MTR and ETR makes the design of the in-pile tubes one of the more difficult problems. This is discussed as well as the problem of the radiation effect on in-pile tube structural materials. Brief mention is made of the complexity of loop controls and some fuel element tests. The deposition of corrosion products in a radiation field is a problem peculiar to in-pile loops. This phenomenon and the failure of the WAPD-30 in-pile tube by corrosion of the 316 stainless steel tip are covered.

IDO-16428

Richardson A S (Editor)
IN-TANK IRRADIATION FACILITIES IN THE MTR AND ETR-STANDARD PRACTICES MANUAL,
Phillips Petroleum Co., Atomic Energy Div., Contract No. AT-(10-1)-205, April 1, 1958, 86 pp.

This document has been prepared as an aid to the experimenter in his planning and designing of capsule-type irradiations in the MTR and ETR. The report represents a complete description of the facilities available for capsule-type irradiations. Standard capsules and capsule holders or baskets are also described. A generalized discussion of typical designs of various types of capsules is included. In addition, the requirements for irradiation of capsule-type experiments are presented. Instrumented capsules and flux monitors are discussed.

IDO-16431

Nertney R J
ENGINEERING LIAISON FOR MTR-ETR EXPERIMENTS STANDARD PRACTICES MANUAL,
Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho, Contract No. AT-(10-1)-205, December 20, 1957, 58 pp. (7 refs).

This is the introductory volume of a series of Phillips Petroleum Company Standard Practices Guides for design of MTR and ETR experiments. The need for and nature of these guides is discussed in general terms.

The presently proposed guides (including those which are completed) are briefly abstracted.

The experiment information outlines, which are prepared for each major engineered experiment at the MTR are discussed, and sample outlines are included in the appendices of this guide.

IDO-16434 (Part I)

Corben H C
EXACT SOLUTION OF THE PILE KINETIC EQUATIONS,
The Ramo-Wooldridge Corp., Los Angeles 45, Calif., July 11, 1957, 10 pp. (5 refs).

The space-independent pile kinetic equations are solved to give the excess reactivity explicitly in terms of the pile power and its history. The need for digital computations

for determining the reactivity from a given power trace is thereby reduced. The solution is applicable to arbitrary variations of power with time and is examined in detail for the case of small damped oscillations about a slowly varying average power and for a power fluctuation occurring during a short time interval. The reactivity compensated during a power surge is computed as a function of the period by fitting the observed power to a simple algebraic expression.

IDO-16434 (Part II)

Horning W A
A MODEL FOR TRANSIENTS IN THE SPERT-I REACTOR,
The Ramo-Wooldridge Corp., Los Angeles 45, Calif., October 4, 1957, 14 pp.

A model of power transients and resonance instability in SPERT-I is presented. The model assumes thermal expansion and void growth as the mechanisms for power-induced reactivity change. The model accounts for the observed features of the initial power peak in a general way. It is more successful, even semiquantitative, as a description of resonance instability as observed in SPERT-I. Further progress requires an improved understanding of void formation in transient boiling.

IDO-16434 (Part III)

Corben H C
THEORY OF SMALL OSCILLATIONS OF THE SPERT REACTOR,
The Ramo-Wooldridge Corp., Los Angeles 45, Calif., July 30, 1957, 8 pp.

The phenomenological treatment of void formation in the SPERT reactor, given in the previous report by W. A. Horning, is combined with the pile kinetic equations, and the resulting system of equations is studied for small oscillations about an average power level ϕ_o. The frequency is shown to be approximately proportional to ϕ_o 1/2, in reasonable agreement with experiment. Damping is predicted to occur below a certain critical power level the value of which depends, among other quantities, on the rate at which voids formed in the water inhibit the production of further voids.

IDO-16463

Haas F C
MAINTENANCE OF ETR COOLANT
Phillips Petroleum Co., Atomic Energy Division, Idaho Operations Office, USAEC,
Contract No. AT-(10-1)-205, August 15, 1958, 11 pp.

The ETR is a thermal reactor using ordinary demineralized water as coolant and moderator. Three resin beds are used for activity reduction and to improve the water quality. Design specifications were for water having a specific resistance of one million ohms, but at 175 megawatts the resistance has only been 400,000 to 500,000 ohms. Iron, aluminum, and beryllium are routinely determined and have been of the same order of magnitude as these in the MTR. No evidence of nitrogen fixation has been found at 80 megawatts. The gross beta-gamma activities are 10,000 at 80 megawatts and 40,000 counts per minute per milliliter at 175 megawatts. The cation exchanger is removing about 90% of the gross activity; the anion is removing about 30%, and the mixed bed about 97%. Gross water activities are twenty times those found in the MTR before fission breaks occurred. Fission products have been found and identified in the primary

water and the gases from the degassing tank. Gaseous activity has necessitated installing a temporary exhaust system on the heat exchanger building and a permanent ventilating system has been designed. The production of gaseous hydrogen and oxygen has presented no problems since the total gas has been 20 to 40 ml/l of water. The primary water is continuously monitored by convection pH and conductivity meters and by a fission break monitor.

IDO-16477

Schaffnit W O
METALLURGICAL EXAMINATION OF A MELTED SPERT-I TYPE-B FUEL PLATE,
Phillips Petroleum Co., Atomic Energy Div., Idaho Operations Office, USAEC,
Contract No. AT-(10-1)-205, September 18, 1958, 18 pp.

Failure in one of the removable SPERT-I Type-B fuel plates was discovered on April 24, 1958, during routine operations that involved removal of fuel plates. The melted plate with two adjacent plates were delivered to the MTR hot cell for metallurgical examination. Macroscopic and microscopic examinations were made. It was concluded that the break resulted from temperatures exceeding the melting points of the 6061 aluminum cladding and the core material.

IDO-24020

Bush P D and Levy S
ENGINEERING TEST REACTOR - ENGINEERING DESIGN AND SAFEGUARDS REPORT,
Kaiser Engineers, Nuclear Engineering Division, Oakland, Calif., and General Electric Co.,
Atomic Power Equipment Department, Schenectady, N.Y., Contract No. AT-(10-1)-770,
July (1956), 286 pp.

The Engineering Test Reactor (ETR) is designed to perform engineering tests on fuel elements and components of nuclear plants. Its main purpose is to provide large experimental facilities with very high neutron fluxes, thus supplementing research reactors already in use. The reactor complex is described in detail and engineering drawings are given for the complete system, including buildings and services. Various operational considerations are evaluated from a reactor safeguards basis.

IGR-R/R-208

Hitchcock A J M, Price V E and Shenton J
FLUX CHANGES IN A THERMAL REACTOR UNDER LONG-TERM IRRADIATION,
United Kingdom Atomic Energy Authority, Risley, Lancashire, June (1957), 120 pp. (16 refs).

This report presents the results of a study of flux changes in a reactor as a result of irradiation. The primary function of this investigation was not to make even a preliminary survey of the dependence of these effects on the various parameters concerned, but to develop methods by which such a survey, or a study of particularly interesting cases, could be carried out, and although the results obtained are of very considerable interest they do not claim to be exhaustive in any sense.

As irradiation proceeds in a reactor, the composition of the fuel is steadily changed by the nuclear reactions taking place. In consequence the lattice constants also undergo steady changes, and are functions of the irradiation received at each point. Since this

varies from point to point in the reactor, so do the lattice constants, and consequently the shape of the neutron flux will also change with time. In addition, the power output per unit flux is also a function of irradiation. Consequently it may be expected that the distribution of power produced over the life of a reactor will vary with time; and also, perhaps, the total power produced. Such changes must be allowed for in reactor design and operation.

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As will appear, the amount of calculation involved in solving this problem, even using the refined methods reported here, is very great. It is estimated that using hand computation methods, an expenditure of labor of fifty man-years per case would be involved, and this is plainly prohibitive. The use of a large scale computor is necessary and since an analogue computor would be highly specialized, it was decided to proceed on an electronic digital computor.

This report does not concern itself with the detailed programming used to solve the problems, nor with the operating instructions for the use of the existing programs with the machines.

IGR-TN/R-641

Hitchcock A
CONTROL ROD REQUIREMENTS IN A THERMAL REACTOR,
United Kingdom Atomic Energy Authority, Research and Development Branch, Risley, Lancashire, August (1957), 6 pp. (1 ref).

This report discusses the method of calculation for control of power level in a reactor. Discrepancies in nomenclature are pointed out. Calculations for both control and safety rods are included.

IGR-TN-R-642

Cutts B
THE CALCULATION OF THE EFFECTIVENESS OF CONTROL RODS ON A THERMAL REACTOR,
United Kingdom Atomic Energy Authority, Industrial Group, Research and Development Br., Risley, Lancashire, August (1957), 9 pp. (5 refs).

This report describes the "super-cell" method of control rod calculations which may be used in reactors containing large numbers of rods as an alternative to the more conventional methods.

IGRL-1B/R-6 (2nd Ed)

Hartas J C
NUCLEAR POWER AND REACTOR ENGINEERING: SELECTED AND ANNOTATED REFERENCES,
United Kingdom Atomic Energy Authority, Industrial Group, Risley, Lanchashire, February (1958), 17 pp. (references)

This report is a compilation of papers and articles selected by the Library and Information Department of the United Kingdom Atomic Energy Authority as a guide to selected reading for those about to enter the nuclear engineering field. Most of the

references are basic, in nature, and cover such subjects as materials, reactors, safety, dosimetry, and waste products.

ISC-318 (Del)

Spedding F H
THE MOLTEN-METAL-FUEL REACTOR,
Iowa State College, Ames Laboratory, Ames, Iowa, Contract No. W-7405-Eng-82,
June (1953), 5 pp.

This report discusses the various early categories of reactors. The molten-metal-fuel reactor is one of these. The advantages of this type of reactor are discussed. Problems are associated with such a reactor, but it is felt that these problems could successfully be solved.

ISC-567

Mitchell R F and Martin D S
HIGH SPECIFIC RADIOACTIVITIES OF OSMIUM FROM PHOTONUCLEAR REACTIONS,
Iowa State College, Ames Laboratory, Ames, Iowa, Contract No. W-7405-Eng-82,
January 29, 1955, 39 pp. (38 refs).

The 70 Mev bremsstrahlung irradiations of Os have prepared a 6 hr. Os activity, $Os^{191,191m}$, Re^{190} (1 hr) Re^{186} and Re^{188}. Thin Os samples were electroplated which allowed a windowless counter determination of absolute disintegration rates. By this method the relative yields of Os^{191}/Os^{191m} were found to be 0.25 ± 0.1. A relative yield, $Os^{192}(\gamma, n)\, Os^{191m}/Cl^{34}\, (\gamma, n)\, Cl^{34}$, of 40 was obtained. The 70 Mev bremsstrahlung irradiations of Ir yielded $Os^{191,191m}$ and 4 hr Os activity. Also produced were $Ir^{190,190m}$ (3 hr and 12 d) and a relatively high yield of 19 hr. Ir^{194} which indicated the presence of a significant neutron flux in the vicinity of the Iowa State College synchrotron donut. A 6-hr Os daughter formed from a 12 d Ir parent was also noted. In irradiations of the compound $(NH_4)OsCl_6$ a Szilard-Chalmers effect was noted. When the target compound was subjected to a nitric acid oxidation 40-60% of the osmium activity distilled with the first few milligrams of OsO_4. Enrichments as high as 40 were obtainable. Only a small fraction of activity was initially collected in an OsO_4 separation so the enrichment depended upon the rate of oxidation of the recoil atoms by nitric acid and it was enhanced by the presence of ammonium ion.

KAPL-329 (Pt. II)

Stewart H B and Gavin G B
ACTIVATION EXPERIMENTS IN THE KAPL PRELIMINARY PILE ASSEMBLIES,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52,
September 20, 1950, 43 pp.

This report is a description of activation experiments in the four assemblies, PPA-2, -3, -4, and -5. The purpose of the experiment was to measure: The power distribution in the reactor core, the fraction of fission resulting from neutrons having energies below Cd cutoff, the spatial distribution of the epithermal flux, and the energy distribution of the epithermal flux.

KAPL-1443

Sullivan L O
PROBLEMS AND COSTS ENCOUNTERED IN THE HANDLING OF IRRADIATED FUELS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, September 1, 1955, 35 pp.

Operating experience in the Radioactive Materials Laboratory is described, with emphasis on problems and costs encountered in the handling of irradiated fuels.

KAPL-1756 (Part 1)

Baraff G A and Mallon R G
THE FAST OXIDE BREEDER - REACTOR ANALYSIS-PART I. NEUTRON YIELDS, CROSS SECTIONS, GROUP CONSTANTS, AND MACHINE ROUTINES,
General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, June 30, 1957, 57 pp. (33 refs).

As part of subcontract K-314, Advanced Scientific Techniques Research Associates (ASTRA) has performed work for KAPL in the area of reactor physics with specific application to the KAPL Fast Oxide Breeder. The results of the first phase of this work, an evaluation of existing information on cross sections in the energy range of interest and on neutron yields for fissionable isotopes, are reported in Section A. The methods and techniques developed for reducing the raw data to group constants for PROD II (the code chosen for multigroup calculations) and modifications made to the PROD II code are discussed in Section B.

KAPL-1756 (Part 2)

Molino D F and Davidson J K
THE FAST OXIDE BREEDER-REACTOR ANALYSIS-PART II. REACTOR CALCULATIONS,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, June 30, 1957, 35 pp. (16 refs).

The results of a new series of multigroup criticality calculations for the Fast Oxide Breeder reactor are reported. A new compilation of nuclear data prepared by ASTRA personnel was used as input.

Among the more important differences between the new results and the original calculations of Luebke and Sampson are:

1. An increase in fuel concentration (uranium/plutonium ratio from 5/1 to 4/1) for the same reactor size and power output,
2. Reduction in the total breeding ratio obtainable from about 1.4 to 1.3, and
3. Use of fuel movement rather than reflector movement for control.

KAPL-1773

Jones Samuel S
HIGH INTENSITY GAMMA IRRADIATION FACILITIES AT THE KNOLLS ATOMIC POWER LABORATORY,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, April 1, 1957, 36 pp.

Information is presented concerning the structure, operation, and radiation fields of two high intensity cobalt-60 gamma irradiation facilities at the Knolls Atomic Power Laboratory. A cylindrical 580-curie source is used in a mobile lead-shielded facility. A second source consists of 3440 curies in ten separate capsules. The capsules are mounted in various holes on a plate in a water-shielded facility. The capabilities of the two facilities tend to complement each other. A variety of irradiation studies have been made with these units during the past five years.

KAPL-1803

QUARTERLY REACTOR TECHNOLOGY REPORT NO. 2,
Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, August 23, 1957, 72 pp.

This report is divided into four major categories: physics, engineering, materials, and chemistry.

A. Physics

1. Uranium lattice studies,
2. Nuclear analysis for stainless steel - water and zirconium - water cores,
3. Pulsed neutron studies,
4. Study of plutonium-fueled reactor cores,
5. Inelastic scattering group parameters,
6. Nuclear temperature as a function of mass and excitation energy,
7. Cylindrical homogeneous reactor with infinite reflector,
8. Application of a variational method,
9. Multigroup codes, and
10. Neutron spectrometry.

B. Engineering

1. Inlet plenum test,
2. Heat transfer coefficient for twisted ribbons (Nickel-plated copper),
3. Interchannel mixing,
4. Twisted ribbon interchannel mixing - experimental techniques, and
5. Control drive mechanisms.

C. Materials

1. Control materials - neutron absorber,
2. Composite control rod development, and
3. Advanced materials development.

D. Chemistry

1. KAPL in-pile crud studies.

KAPL-1868

QUARTERLY REACTOR TECHNOLOGY REPORT NO. 3,
July, August, September, 1957, Knolls Atomic Power Laboratory, Schenectady, N.Y., Contract No. W-31-109-Eng-52, (1957), 78 pp.

This report summarized the progress made at KAPL during July-September 1957. A partial listing of subjects covered includes reactor physics, reactor engineering, and reactor materials and chemistry.

KAPL-M-RWD-17

Deutsch R W
NUCLEAR EVALUATION OF SLAB-TYPE CONTROL RODS,
Knolls Atomic Power Laboratory, Schenectady, N.Y.,
Contract No. W-31-109-Eng-52, December 19, 1956, 16 pp. (2 refs).

In order to introduce the epithermal control rod effects for a slab geometry, a two-group method analogous to the one-group method, which has been used for the absorption area method, is developed. The two-group method in conjunction with experimental measurements permits the determination of epithermal cross sections for individual rods as well as the determination of the rod worth of a group of rods.

A semiquantitative analysis of FPR and ATR experiments is in agreement with the theory.

KAPL-M-S3G-RES-23

Fraser J P
INTERCHANNEL MIXING,
General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N.Y., April 12, 1956, 10 pp.

This report discusses a method developed by which the temperature rise in a reactor may be corrected for interchannel mixing if the heat generation may be assumed to vary, in the transverse plane, in one direction only. This assumption is approximately satisfied in many regions of the rhombus matrix. The application of this method to reactor design will be written up after diffusion coefficients have been measured.

KLX-63

DETAILED PROJECT STATUS REPORT - JAW TYPE REMOTE CONNECTORS,
The Kellex Corporation, N.Y., Contract No. AT-(30-1)-Gen-169, August 26, 1949, 21 pp. (10 ref).

The 4-inch jaw-type connector designed for this project is similar to the smaller connectors of the same type and essentially all of the design features of the smaller connector were incorporated in the 4-inch model. Initial testing of the model produced generally satisfactory results, but additional testing and modification would be required to check out the design before a prototype could be fabricated.

KLX-1395

MTR RODS AS FISSION PRODUCT SOURCES FOR INDUSTRIAL STERILIZATION,
Vitro Corporation of America, N.Y., N.Y., Contract No. AT-(30-1)-850, January 2, 1954, 33 pp. (14 refs).

The industrial utilization of fission products as sterilization devices for foods, drugs, and other materials will require sources in the megacurie range. Considerable chemical research and development will be necessary before sources of this magnitude can be made available. One possibility for acquiring a high strength source would be the direct utilization of Materials Testing Reactor (MTR) fuel elements from the reactor after a brief cooling period. These rods would require neither chemical processing (to recover fission products) nor source fabrication prior to use in a pilot plant (as a high level radiation facility).

An engineering and economic feasibility study has been made relative to the possibility of using MTR fuel rods as gamma radiation sources.

In the engineering feasibility study, three concepts of a pilot plant design using MTR rods for industrial sterilization were considered. Although these designs are based on MTR fuel assemblies as radiation sources after they are removed from the reactor, sufficient flexibility is provided in each design to accommodate sources of other geometric shapes, e.g., slabs, hollow cylinders and rods. On the basis of the reactor data used in this study, it is estimated that a complete set of 23 fuel elements would provide approximately one megacurie at the time the source is installed and about an average of half a megacurie for two months.

In the economic study, over-all costs of MTR sources to potential consumers were based on estimated of the following component costs:

1. Cost of transporting MTR fuel elements from the reactor (after a brief cooling period) via a shielded railroad flatcar.
2. Consumer installation and processing costs. (The installation costs are not related to the pilot plant design.)

A cost comparison of MTR rod sources with the present day costs of an (approximately) power equivalent electron accelerator (0.5 kw) is included. This comparison should not be interpreted to mean that electron accelerators are similar in all respects to gamma ray sources as radiation devices. It is intended rather as an indication of approximate comparative radiation costs.

KLX-1612

CONVERSION OF UF_6 TO HOMOGENEOUS REACTOR FUEL (57-D),
Vitro Corporation of America, N.Y., N.Y., Contract No. AT-(11-1)-217, April 1, 1953, 81 pp.

Methods have been investigated for the conversion of UF_6 to UO_2SO_4 suitable for use as homogeneous reactor fuel. Throughputs of both 2000 lb and 11 lb of uranium per day were considered.

The process developed and demonstrated on a laboratory scale for 2000 lb of uranium per day throughput of slightly enriched UF_6 (approximately 1% U^{235}) comprises hydrolyzing UF_6 in 70% H_2SO_4, air sparging of the hydrolysis product at 90°C to remove HF, filtering the resultant UO_2SO_4 crystals and calcining the crystals at 500°C. The process developed and demonstrated on a laboratory scale for 11 lb per day throughput of highly enriched UF_6 (over 90% isotopic U^{235} purity) comprises hydrolyzing UF_6 in water, adding a slight excess of H_2SO_4 and drying and calcining at 500°C.

KT-183 EPS-X-222

Rossin A D, et al.
P^{32} PRODUCTION IN THE X-REACTOR,
Massachusetts Institute of Technology, Engineering Practice School, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 27, 1954, 28 pp. (7 refs).

A method is presented for calculating the rate of production of P^{32} in the X-10 Graphite Reactor in order to determine the most efficient schedule for the irradiation of cans of sulfur in the reactor. Variables in the process are the number of cans inserted each week and the length of time and level of irradiation of each can. Limitations are imposed by the demand for P^{32}, the high cost of chemical processing, availability of reactor space, and the operating schedule for the reactor. The distribution of neutron flux responsible for the reaction is determined by the irradiation of aluminum sulfate and details of the method are discussed. The results of the study indicate that no other production schedule offers a sufficient increase in efficiency over the schedule now used to justify a change.

LA-1441

Hansen G E
BURST CHARACTERISTICS ASSOCIATED WITH THE SLOW ASSEMBLY OF FISSIONABLE MATERIALS,
Los Alamos Scientific Laboratory, Los Alamos, N.M., July (1952), 39 pp.

This report is a sequel to LA-596, "Efficiency for Very Slow Assembly," by K. Fuchs. Herein are given estimates of temperature rise and pressure developed as a result of active material slowly being driven supercritical. Marginal assembly rates can thus be determined for both metal and solution assemblies above which the disassembly by thermal expansion is explosive in the sense that the active material or containing vessel is ruptured.

LA-1942

King L D P
A BRIEF DESCRIPTION OF A ONE MEGAWATT CONVECTION COOLED HOMOGENEOUS REACTOR - LAPRE II,
Los Alamos Scientific Laboratory, Los Alamos, N.M., Contract No. W-7405-Eng-36, April 13, 1955, 17 pp. (reference).

The design of LAPRE II, a homogeneous 1 Mw thermal reactor is given. This reactor is intended to be simple, reliable and foolproof and operated without attendants after initial testing.

The fuel is UO_2 in H_3PO_4 and the sealed system permits the removal of the fuel solution to a noncritical reservoir in the event of a high pressure development.

The information to be gained from the operation of this reactor concerns the long term corrosion resistance of the materials subjected to this fuel solution and to demonstrate the feasibility of compact, portable, simple and reliable reactor.

Details of the graphite moderator and heat exchanger are given.

LAC-NR-51 (Vol. I)-4

Jones S S, Langdon W R and Naydan T T
NEW RADIATION TEST FACILITIES IN THE GENERAL ELECTRIC COMPANY,
General Electric Company, General Engineering Laboratory. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Ga., October 28-30, 1958, 30 pp. (1 ref).

This paper describes new radiation test facilities either in operation or now being installed by the General Electric Company. These facilities have been financed entirely by General Electric Company funds and are located in its General Engineering Laboratory, Schenectady, N.Y., and its Vallecitos Atomic Laboratory, Pleasanton, Calif. These combined facilities will provide radiation sources and equipment for nearly all types of radiation work -- for studies on materials or machinery; for basic research or for qualification testing; and for studies using charged or uncharged, light or heavy particles.

LAC-NR-51 (Vol. I)-5 FZM-1153

Allen J W
THE CONVAIR RADIATION EFFECTS TESTING SYSTEM,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corporation, Marietta, Ga., October 28-30, 1958, 11 pp.

This paper and an accompanying movie describe the radiation effects testing system at Convair-Fort Worth, including the shuttle system to transport specimens in special environmental chambers. The hardware and controls necessary to meet the environmental criteria and the versatility of the system are described.

LAC-NR-51 (Vol. I)-6

Scarborough W T
RADIATION EFFECTS REACTOR,
Lockheed Aircraft Corp., Marietta, Ga. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corp., Marietta, Ga., October 28-30, 1958, 10 pp.

The radiation effects reactor is a 10-megawatt, pressurized, heterogeneous, light water cooled and moderated reactor, using fully enriched uranium in ETR-type elements. It is mounted on a hydraulic lift, which raises it from the pool to the height of the systems mounted on railroad cars around the pool for irradiation. Coolant flows through swivel pipes at 3000 gpm. Control and instrumentation cables are routed through an overhead conveyor system to lessen radiation damage to them.

A new core will contain 11.6% Δk excess reactivity and have a lifetime of 7000 megawatt hours at rated power. Calculated flux values at the pressure vessel surface are thermal neutron current - 3 x 10 in. nv, above thermal neutron current - 8 x 10 in. nv, and gamma flux - 6×10^{13} mev/cm^2-sec.

LAC-NR-51 (Vol. I)-8

Dewar M A
START-UP OF THE CRITICAL EXPERIMENT REACTOR,
Lockheed Aircraft Corp., Marietta, Ga. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, Lockheed Aircraft Corp., Marietta, Ga., October 28-30, 1958, 6 pp.

The Critical Experiment Reactor operated at Air Force Plant No. 67 by Lockheed Nuclear Products Branch is used to establish core loadings for the Radiation Effects Reactor and to determine all pertinent nuclear characteristics of each RER core.

The CER was designed, manufactured, and installed by the Atomic Power Equipment Department of General Electric Company. Facility design was by Lockheed. Facility construction was begun December 27, 1957; and installation of the CER was begun April 9, 1958.

Criticality was achieved June 9, 1958, with a rectangular 20-element array containing approximately 3.260 kg U^{235} and having approximately 0.3% excess reactivity. The four fuel-poison control rods were determined to have a shutdown worth of approximately 4-1/2% $\Delta k/k$ each. The silver-cadmium regulating rod is worth approximately 0.3% $\Delta k/k$ negative reactivity. The RER operational loading, containing 11.6% reactivity, was achieved in the CER with a 32-element array, approximately 5.372 kg U^{235}. For this core the temperature coefficient is negative, approximately $-7.01 \times 10^{-5} \Delta k/k$ per ^{o}C at $75^{o}F$. The void coefficient is approximately $-4.35 \times 10^{-4} \Delta k/k$ per cent void. The critical and operational core loadings, rod worth, and coefficient values were in good agreement with previously calculated values.

Operation has proved the CER to be stable and simple to control; and, since the initial "bugs" in the instrumentation channels and in the mechanical systems have been eliminated, most of the systems have been trouble-free.

LAMS-2126

Watt, Bob E
SUGGESTIONS ON THE DESIGN OF HETEROGENEOUS REACTORS,
Los Alamos Scientific Laboratory, Los Alamos, N.M., Contract No. W-7405-Eng-36, June 14, 1957, 4 pp. (1 ref).

Several safety suggestions whereby reactor core materials are moved to regions of lower flux in the event of catastrophe are given. The use of a spinning core and entry of coolant thru channels containing no active material might contribute to safety. The use of a fuel element incorporated in a bimetallic strip is noted.

MDDC-1080 LADC-406

Hall David B and Hall Jane
LOS ALAMOS FAST REACTOR,
Los Alamos Scientific Laboratory, Los Alamos, N.M. (1947), 1 p.

The Los Alamos Scientific Laboratory of the USAEC under the direction of Dr. Norris E. Bradbury, has announced the initial operation of a new type of neutron reactor which operates on the fission of plutonium by high energy neutrons. The fact that the fission

process proceeds by use of high energy neutrons has led to the name of "fast" reactor. Since the other existing reactors in the US use uranium as the active material and thermal or slow neutrons for producing fission, the fast reactor is new in the field of atomic energy developments.

Since the neutron and gamma radiations from nuclear reactors are of such high intensity that it is impossible to remain in the vicinity of an unshielded unit, the entire reactor is surrounded by a concrete and steel shield of sufficient thickness to reduce adequately the intensity of these radiations. Experiments can thus be carried out adjacent to the reactor without danger or inconvenience.

The reactor is now in the final construction stages, but has been operated successfully at low power since November 1946. It is planned by the Laboratory to have the reactor completed in the Autumn of 1947, after which time it should be operating at a power level of several kilowatts and in use by the Laboratory as a source of high energy neutrons for nuclear physics investigations and as a pilot plant to investigate the possibilities of future high power atomic energy installations.

Numerous facilities are provided for irradiating materials in the neutron flux of about 10^{12} neutrons per cm^2 per second and for allowing intense beams of moderately high energy neutrons to emerge from the reactor. In order to increase the versatility, a graphite thermalizing column is provided on one side of the reactor so that both fast and slow neutrons are available for experimental studies.

MIT-5007

Thompson T S, et al.
FINAL HAZARDS SUMMARY REPORT TO THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS ON A RESEARCH REACTOR FOR THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Mass. Institute of Technology, Cambridge, Mass., January (1956), 127 pp.

This document presents the final hazards summary report on a research reactor for the Mass. Institute of Technology. Included in the report are description of the location and reactor; a discussion of instrumentation and controls; personnel and organization requirements; reactivity requirements and a discussion of hazards and accidents.

Six appendices are included and are: Reactor Calculations; Effect of a Shadow Shield on the Gamma Ray Dosage Received at Points Outside the Reactor Building; Dosage of Radiation Resulting from Building Outleakage; Control Element Drop Tests; and Pressure Rise in Building Due to Aluminum-Water Reaction.

Mon P-271

Newson Henry W
THE CONTROL PROBLEM IN PILES CAPABLE OF VERY SHORT PERIODS,
AEC Research and Development Report, Contract No. W-35-058-Eng-71, April 21, 1947, 34 pp.

This report discusses the control problem in piles capable of very short periods. Specific topics discussed within this report are ranges of control, start-up accident, period and power control, and conditions of control.

NAA-SR-104

Kash Sidney W, Martin Elaine and Cohen Richard E
NEUTRON PRODUCTION REACTOR EXPERIMENTS IN THE EXPONENTIAL ASSEMBLY,
North American Aviation, Inc., Nuclear Engineering and Manufacturing, P.O. Box 309, Downey, California, Contract No. AT-(11-1)-Gen-8, January 1, 1956, 18 pp. (8 refs).

This report presents results of measurements made in conjunction with the design of a natural uranium heavy water Neutron Production Reactor. The bucklings of eight natural uranium heavy water lattices, including cooling water air channels and aluminum discs to simulate canning, were experimentally determined. An analysis of the data is also given showing that the measurements are not inconsistent with previously developed theories.

This report is based on studies conducted for the AEC.

NAA-SR-116 (Del)

Mills M M
ON THE HAZARD DUE TO NUCLEAR REACTORS,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, 66 pp. (39 refs).

A major hazard associated with any nuclear reactor is the possible contamination of the atmosphere or water supply by the accidental release of the radioactive materials contained within the core. This problem can be considered in two stages: (1) the technical sequence of events leading to the hazardous release of radioactive materials from the reactor, and (2) the distribution of this radioactivity by meteorological and hydrological mechanisms. The second problem is not considered here since it is treated adequately elsewhere.

The possible mechanisms of reactor catastrophe are mechanical disruption, cooling failure, and reactor runaway. Sabotage seems to be the most probable cause of mechanical disruption. On the basis of the theoretical studies which have been carried out, cooling failure and reactor runaway seem to lead to the same type of behavior. The possibility of building a reactor which is intrinsically safe because of a large negative transient temperature coefficient is demonstrated with an example.

NAA-SR-1477

Gilbert W S
THE USE OF CYCLOTRON IRRADIATION IN THE STUDY OF RADIATION EFFECTS ON MATERIALS; TECHNIQUES DEVELOPED SINCE 1952,
North American Aviation, Inc., Atomics International, P.O. Box 309, Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, March 15, 1956, 16 pp.

Recent developments (since 1952) of techniques for the study of irradiation effects on materials using a cyclotron are described. Details of methods covering both metals and graphite over a temperature range of irradiation from -196° to $+500^{\circ}$C are given. Also included are details of an instantaneous cyclotron-beam monitor.

NAA-SR-1525

Remley Marlin E, et al.
PROGRAM REVIEW OF THE WATER BOILER REACTOR KINETIC EXPERIMENTS,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, March 15, 1956, 85 pp. (13 refs).

A series of reactor kinetic experiments will be performed on low power homogeneous reactor cores at the North American Aviation Field Test Laboratory in the Santa Susana Mountains near Los Angeles, Calif. Initial tests will be concerned with a spherical geometry core similar to the Los Alamos "SUPO" type water boiler. Subsequent tests are tentatively planned to include both open and closed cylindrical geometries. The experimental facility, apparatus, and program are described. Theoretical studies made in preparation for the program include analogue computations of power versus time and total energy release for various step increases in reactivity. The calculations include the effects on reactivity of radiolytic production of gas and of inertial pressure increases during the transients. Analysis of reactor oscillations which permit the determination of heat transfer characteristics, prompt neutron lifetime and effective fraction of delayed neutrons is given.

NAA-SR-1704

Colichman E L, Mallon P J and Jarrett A A
A LABORATORY FACILITY FOR IRRADIATION AT ELEVATED TEMPERATURES,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, January 1, 1957, 21 pp. (5 refs).

A laboratory irradiation facility has been designed and built using 2000 curies of cobalt-60 inside a 3-ton movable dome. Relatively large volumes can be irradiated with highly uniform dose rate distributions. Radiation levels are reproducibly adjustable from 10^4 to 2.5×10^6 r/hr. The source was designed to permit irradiations at temperatures up to 450°C. Since the average external radiation level is less than 0.1 mr/hr, the facility can be used in a laboratory equipped with radiation measuring equipment and continuous access by personnel.

NAA-SR-1800

Trilling C A
ORGANIC MODERATED REACTOR EXPERIMENT QUARTERLY PROGRESS REPORT,
AUGUST - OCTOBER, 1956,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, November 15, 1957, 102 pp.

This report comprises a comprehensive review of technical progress on the Organic Moderated Reactor Experiment (OMRE), which is being constructed and will be operated at the National Reactor Testing Station at Arco, Idaho. This is the second report of the series, and covers the period from August 1, 1956 through October 31, 1956. The previous report (NAA-SR-1700) is entitled: Organic Moderated Reactor Experiment - First Progress Report, October 1956 - July 1957.

NAA-SR-1833

Banks W F, et al.
AN EVALUATION OF THE COLDER HALL TYPE OF NUCLEAR POWER PLANT,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, January 19, 1957, 106 pp. (37 refs).

Presented herein is the preliminary design of a natural uranium, graphite-moderated, CO_2-cooled reactor and power plant similar to, but larger than, the British Calder Hall plant, with a net electrical output of 130 MWE. The design is conventional, consisting mostly of standard components, the only major uncertainty being the performance of the fuel cladding. A construction cost of $67 million and a power cost of 17 mils/kwh are estimated for this plant, assuming private utility operation in the US, which is about three times the cost of power from conventional plants.

Power output and cost for various conditions of temperature and pressure and for increased reactor size are calculated. It is estimated that a similar plant of 740 MWE output would produce power at a cost of 10 mils/kwh. Use of helium as coolant is investigated and found to offer no advantage over CO_2.

NAA-SR-1934

Armenoff C T and Binstock M H
FUEL ELEMENTS FOR THE ORGANIC MODERATED REACTOR EXPERIMENT,
North American Aviation, Inc., Atomics International, P.O. Box 309, Canoga Park, Calif.,
Contract No. AT-(04-3)-88, December 15, 1957, 82 pp. (4 refs).

The development of a floating-plate-type fuel element for the organic moderated reactor experiment is described. The fuel element is a stainless-steel box containing 16 active fuel plates which "float" in longitudinal grooves. The floating plates minimize distortion caused by the large temperature differences experienced with the use of an organic coolant. The fuel plates consist of a core of highly enriched UO_2 particles uniformly dispersed in a stainless-steel matrix clad with stainless steel.

Techniques for fabricating the fuel plates are also described. The fuel plate is fabricated by hot- and cold-rolling a 3/8-inch thick sandwich assemble into the 0.030-inch thick fuel plate. The sandwich consists of a stainless steel-UO_2 compact encased by a frame and two cover plates of stainless steel.

Development of a nondestructive gage to detect variations of UO_2 content in the fuel core of the finished plate and a method of attaching five-mil-diameter thermocouples to five-mil-thick fuel core cladding are noted.

NAA-SR-1954

Miller Norman C
REACTOR SAFETY PROGRESS REPORT, AUGUST-DECEMBER, 1956,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, August 15, 1957, 21 pp.

The lifetime testing of the Mark II Safety Device was resumed; however, four of the six test elements leaked due to excessive rework of parts. The assemblies are being rebuilt using new parts insofar as possible.

Further, tests on the thin-slab experiment have confirmed the previously obtained value of 112 seconds for thermal relaxation time. Tests on the effects of convection and radiation heat loss indicate that higher chamber pressures decrease the thermal relaxation time; the effects were more pronounced with the thinner test slabs.

NAA-SR-1955

Banks W F
A FURTHER EVALUATION OF THE CALDER HALL TYPE OF NUCLEAR POWER PLANT,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, June 28, 1957, 30 pp. (23 refs).

This report presents the results of plant optimization studies and cost estimates of the reference design for a natural uranium, graphite moderated, gas-cooled reactor, and power plant which was described in NAA-SR-1833. Additional engineering drawings are included, some of which were required because of changes in turbine plant and others for estimating purposes.

A construction cost estimate of $70 million for a 165 MWE plant is presented in detail, leading to power costs of approximately 14 mils/kwh, assuming private utility operation in the US.

NAA-SR-1972

Moore M N
THE DETERMINATION OF REACTOR TRANSFER FUNCTIONS FROM MEASUREMENTS AT STEADY OPERATION,
North American Aviation, Inc., Atomics International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, August 15, 1957, 16 pp. (9 refs).

Upon application of the theory of stochastic processes to reactor kinetics it is possible to show that the square of the modulus of the reactor transfer function is proportional to the Fourier transform of the auto-correlation function for power noise in the reactor. Since the power noise represents the response to the minimum power input signal, measurements of transfer functions based upon reactor noise are of all possible measurements, least subject to nonlinear distortion.

By performing the experiment at various power levels and temperatures, it is possible to measure both power and temperature coefficients. If the reactor is periodically monitored during its operation, long-term changes can also be measured.

NAA-SR-2003

Weeks C C
ELECTRICAL ANALOG APPLICATION TO A REACTOR SAFETY DEVICE PROGRAM,
North American Aviation, Inc., Atomic International, Canoga Park, Calif.,
Contract No. AT-(11-1)-Gen-8, November 15, 1957, 27 pp. (4 refs).

An electrical analog was constructed and used to investigate thermal transient behavior of the fuse component of the AI Mark II Reactor Safety Element. The auxiliary instrumentation required in this application is described and discussed. Experimental results are given for thermal relaxation time determinations as well as fuse delay times for exponential transients representing reactor excursions. Convenience, speed, flexibility, and economy of this experimental method are emphasized.

NAA-SR-2004

Hallett W J and Leppard J A
THE EXPERIMENTAL DEVELOPMENT OF A FUEL HANDLING SYSTEM FOR THE SODIUM REACTOR EXPERIMENT,
North American Aviation, Inc., Atomics International, P.O. Box 309, Canoga Park, Calif., Contract No. AT-(04-3)-49, January 15, 1958, 48 pp. (4 refs).

A fuel handling system has been developed from concepts based on early design studies of sodium cooled, graphite moderated reactors. This report describes the development program, the evolution of design leading to the construction of the SRE refueling cask and the tests performed on a mock-up of the equipment. Because of the novel conditions encountered, a rather detailed chronological account is given of the experimental development. Emphasis is placed on the difficulties which arose and the specific means utilized to overcome them.

The equipment and procedure available at the conclusion of the development effort would permit removal and replacement of a fuel element in the SRE core in about 54 minutes. The amount of sodium carried over by a spent fuel element was found to be between 0.1 and 0.25 pounds. Sodium transferred in the gas phase during the fuel replacement process was found to be of the order of a few micrograms. Reliable provisions were evolved for all steps of the operation, including locating the fuel handling cask, sealing the cask and reactor atmospheres, connecting with the cleaning cell and washing down the removed element.

NAA-SR-2057

Weisner E F
ORGANIC MODERATED REACTOR QUARTERLY PROGRESS REPORT, APRIL-JUNE, 1957,
North American Aviation, Inc., Atomics International, Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, March 1, 1958, 69 pp.

Work has been progressing on the development of components and systems for the Organic Moderated Reactor (OMR). Studies are under way for finding optimum parameters of fuel element design, flow rate, temperatures, and pressures in the primary system. Some tests have been performed on components of the control rod; several fuel element cladding techniques have been made on representative samples of possible fuel element configurations.

Equipment has been ordered and some has been received which will permit measurement of the physical properties of organics, measurement of gas solubilities, and determination of the components of irradiated organics. Corrosion samples have been sent to the OMRE for insertion when the reactor is loaded. The in-pile specimens are located in dummy fuel elements adjacent to the core; the out-of-pile specimens are located in the by-pass heater loop.

The project is generally on schedule, and results are bearing out previous expectations.

NAA-SR-2151

Mahlmeister J E
PRELIMINARY DESIGN OF A CALANDRIA CORE FOR THE SODIUM REACTOR EXPERIMENT,

North American Aviation, Inc., Atomics International, P.O. Box 309, Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, 58 pp.

This report considers the design aspects of a calandria-type replacement core for the sodium reactor experiment. This alternate core design has been made in consideration of the possibility that the existing zirconium moderator cans might fail so frequently that the reactor becomes incapable of satisfactory operation. The report covers the calandria description and design basis, expected steady-state performance, and the methods and procedures for core cavity preparation and calandria installation. Recommendations are given for studies and tests which should be performed to confirm areas of detailed design and to further develop methods which would insure a successful core-changing operation.

NAA-SR-2157

Miller Norman C
REACTOR SAFETY QUARTERLY PROGRESS REPORT, JAN-MAR 1957,
North American Aviation, Atomics International, P.O. Box 309, Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, December 1, 1957, 20 pp.

Seven special safety elements of the Mark II design were rebuilt and are ready for resumption of lifetime testing.

Precision-cast parts were received for ten Mark IV high-pressure chambers; one set was assembled and pressure tested to 2000 psi.

Two special assemblies of the NAA-109-3 experiment were completed and are being shipped to Hanford.

Conductivity measurements on stainless steel were continued in an effort to determine the cause of erratic behavior of the variable-cooled trigger. A vacuum chamber was used in an effort to eliminate local heat loss due to convection.

A study of corrosion rates of various container materials in liquid-metal poisons has been undertaken.

NAA-SR-2224

Miller Norman C
REACTOR SAFETY QUARTERLY PROGRESS REPORT, APRIL-JUNE, 1957,
North American Aviation, Inc., Atomics International, P.O. Box 309, Canoga Park, Calif., Contract No. AT-(11-1)-Gen-8, March 15, 1958, 22 pp.

A NAA-109-3 experimental assembly was inserted into a Hanford reactor. Pressure rise in the poison storage chamber was much higher than expected, and caused a failure in the system. Excessive gamma heating is proposed as a plausible explanation.

Results are tabulated for the lifetime testing of six rebuilt test elements of Mark II design.

Experiments were conducted on dispersal of a powdered poison by a pressurized inert gas. The time and uniformity of powder distribution were studied. These experiments are connected with the power reactor safety device program.

Test results are reported on an experimental model of the differential pressure device for power reactor safety, using an improved test apparatus.

Progress is reported on the KEWB demonstration of the double-diaphragm and electronic-explosive systems which have been proposed for research reactor safety devices.

NAA-SR-2323

Sletten H L
ORGANIC MODERATED REACTOR EXPERIMENT SAFEGUARDS SUMMARY,
North American Aviation, Inc., Atomics International, P.O. Box 309, Canoga Park, Calif.,
Contract No. AT-(04-3)-88, February 1, 1958, 139 pp. (references).

This report presents a description of the Organic Moderated Reactor Experiment (OMRE), of the hazards associated with this experiment, and of the safe-guards taken to ensure the safety of the operating personnel and the population of the surrounding area.

The OMRE facility is located at the National Reactor Testing Station at Arco, Idaho. It includes the reactor, its cooling system, and auxiliary equipment, as well as the buildings and services associated with the installation. It is to operate for one year and provide the information required to determine the feasibility of the concept of using a hydrocarbon as moderator, reflector, and coolant in a nuclear reactor under conditions of exposure to heat and radiation of interest in the generation of useful power.

Various extreme accidents and hazards and their possible consequences are analyzed, and the safety measures taken to prevent their occurrence are described. It is concluded that even in case of the most improbable and most extreme credible accident, the OMRE will not constitute a hazard to the population of the surrounding area.

NAA-SR-Memo-195

Ashley R L
RADIOLOGICAL HAZARDS OF THE AIR SURROUNDING THE LPR,
North American Aviation, Inc., Downey, Calif., February 15, 1952, 10 pp. (6 refs).

One of the problems arising from the design of the LPR is the production of A^{41} made by neutron capture in A^{40} present in air. Air is present both in the reflector and in the air gap between the reflector and shield. Due to the increase in overall temperature of the reactor and components during startup, the air expands and is forced into the room. As would be expected, amounts of each of the elements of which air is composed will become radio-active. The amount is a function of the relative abundance in air of the isotope which can be made into the radioactive nuclide, its cross section and half-life. Argon, because of its relatively large abundance in air (compared to the other components) and its large cross section, has a high yield. It can be shown that about 20 curies of A^{41} are made in the reactor air, whereas not more than 40 millicuries of all other isotopes are produced, most of the latter activity being due to He^{22} and Kr^{84}. All the calculations which follow are concerned with the A^{41} activity only, the others being relatively unimportant.

This report will comply with both the transient and steady states and will give practical recommendations from the health physics point of view.

NARF-56-15R

PRELIMINARY SAFETY ANALYSIS OF THE RADIATION EFFECTS REACTOR,
Engineering Dept., Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, September 24, 1956, 78 pp. (references).

This report is a revision of a former report of the same title. The original report described a proposed facility with a 10-megawatt reactor of the MTR type. Since the time of the original report, the proposed facility has been redesigned to reduce the total cost and to provide a better blast and fission-product containment vessel. The pool water activation has been recalculated in this latter report, and more detail is presented on the ventilation system.

NARF-56-27T-4 MR-N-122-4 X-21882

PROCEDURES FOR SYSTEM PANELS TEST NO. 2 - ADDENDUM 4,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)-32054, September 7, 1956, 115 pp.

System Panels Irradiation Test No. 2 was performed at Convair-Fort Worth during late 1956 and early 1957. In this test, existing aircraft systems mounted on test panels were irradiated, using the Ground Test Reactor (GTR) as the source. The GTR was placed in the dry pool, and the panels to be irradiated were grouped around the reactor inside the pool. Measurements were made of the physical properties and operating characteristics of the panel before, during, and after irradiation.

This report is the fourth addendum to Procedures for Systems Panels Test No. 2 (Convair-Fort Worth Report MR-N-122). It describes the equipment that was furnished for this test by the Thompson Products, Inc., of Cleveland, Ohio, and Convair-Fort Worth. Essentially, the equipment consists of a Power Plant Fuel Control System, and a Capacitance-Type Fuel Quantity Gage System, MIL-G-7817.

NARF-57-2T MR-N-148

Romanko J
THE NEUTRON FLUX SPECTRUM OF THE GTR,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF33(600)32054, January 30, 1957, 21 pp. (9 refs).

The neutron flux spectrum of the Ground Test Reactor (GTR), a water-moderated thermal reactor, has been determined at a position 3-1/2 in. from the north face of the core. Measurements were made for three neutron energy regions: thermal, 1-10 kev, and 2.5 to 8 Mev, from data obtained with BF_3 counters, resonance detectors, and threshold detectors, respectively.

A theoretical flux spectrum was obtained for the fast-neutrons from a model consisting of a simple proton-moderated reactor fissioning U^{235}. This spectrum was fitted through the threshold and resonance detector measurements by normalizing at 3 Mev. The accuracy of the spectrum is well within the limits of experimental error. On extrapolating the dE/E component towards lower energies, the theoretical spectrum is consistent with the experimental thermal-neutron flux data.

The correlation of experimental and theoretical results indicated that a three-group specification, consisting of a Maxwellian component, dE/E contribution, and fast-neutron spectrum, is sufficient for the GTR.

NAVORD-4286

Fye Paul M and Noonan E C
NOL REACTOR SAFETY PROGRAM,
US Naval Ordnance Laboratory, White Oak, Maryland, April 30, 1956, 7 pp. (2 refs).

This report consists of a paper prepared for the US - UK Reactor Hazards Meeting held on June 1956, at the Argonne National Laboratory. In order to predict what may happen during reactor runaway, the Naval Ordnance Laboratory has embarked on a program of scaled studies of possible reactor incidents. A discussion of the principles of scaling and examples of the scaling of other explosion phenomena are cited.

NAVORD-4542

Wise Walter R, Jr.
NOL REACTOR VESSEL CONTAINMENT PROGRAM: (NOL-285, DAMAGE FROM EXPLOSION OF NUCLEAR REACTORS),
Quarterly Progress Report for the period January 1, 1957 to March 31, 1957, US Naval Ordnance Laboratory, White Oak, Maryland, June 28, 1957, 13 pp. (2 refs).

The purpose of the NOL Reactor Vessel Containment Program is to produce basic information which will assist in determining the optimum containment design of nuclear reactor vessels. It is planned that the purpose will be achieved through a fundamental investigation of the structural response of water-filled, steel cylinders to internal static and dynamic loading. Progress of the work to date consists essentially of designing the mechanical paraphernalia for scaling and constraining the model test cylinders, and designing and developing the means for monitoring the pressure, temperature, and strain phenomena which accompany excursion-simulated loading of the model vessels. Paralleling experimental effort, the energy equations of dynamic equilibrium for right-circular cylinders closed with rigid constraints at the ends have been derived in closed form. These equations constitute the fundamental analytic tool for the work, and in conjunction with experimental data, will determine the maximum energy absorption potential of various materials, configurations, and constraints; and hence, optimum containment design.

NAVORD-5747

Fisher E M and Wise W R, Jr.
CONTAINMENT STUDY OF THE ENRICO FERMI FAST BREEDER REACTOR PLANT,
US Naval Ordnance Laboratory, White Oak, Maryland, October 7, 1957, 24 pp. (8 refs).

A study has been made on the ability of the Enrico Fermi fast breeder reactor plant to contain a nuclear excursion equivalent to the violence produced by 1000 pounds of TNT. The results of the study indicate that the reactor plant can contain shock waves developed in the air and in the sodium, and also fragments from the cylindrical covering materials surrounding the reactor core. The rotating shield plug, however, is a serious hazard when projected by the gun action of the internal blast pressure in the reactor compartment. This problem is analyzed and a recommendation has been made to lessen the danger.

A greater hazard from the rotating plug can result from a slower (nonexplosive) energy release; however, it has not yet been determined by APDA whether a slower energy release as postulated in this report is possible.

NC-1958-1 NC-1958-2

SIXTH HOT LABORATORIES AND EQUIPMENT CONFERENCE,
1958 Nuclear Congress, International Amphitheatre, Chicago, Ill., March 19-21, 1958.

The papers from this conference are presented in two volumes. The following is a list of those papers and the authors:

Durrill, D. C., et al., "New Multi-Cell Facility in Idaho," General Electric Co., Cincinnati, Ohio.

Steele, R. V., et al., "Pratt-Whitney Aircraft Hot Cell Facility," Pratt & Whitney Aircraft, Livermore, California.

Ward, E. C., et al., "Remote Metallography at Pratt-Whitney Aircraft Hot Cell Facility," Pratt & Whitney Aircraft, Livermore, Calif.

Arehart, T. A., et al., "Segmenting Cells for Dismantling In-Reactor Experiments," Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Altamari, L. A., et al., "New Chemistry Cell and Hot Waste Disposal System at the Knolls Atomic Power Laboratory," General Electric Co., Knolls Atomic Power Lab., Schenectady, N.Y.

Bernstein, G. J., et al., "Design for a Remotely Operated Facility for High Temperature Processing of Spent Reactor Fuel," Argonne National Laboratory, Lemont, Illinois.

Hampson, D. C., et al., "Equipment for Purification of Spent Reactor Fuel by Melt Refining," Argonne National Laboratory, Lemont, Illinois.

Ferguson, K. R., et al., "Shielding Window Design for the EBR-II Process Plant," Argonne National Laboratory, Lemont, Illinois.

McCown, J. J., et al., "Analytical Junior Cave Facility for EBR-II," Argonne National Laboratory, Lemont, Illinois.

Doe, W. B., "Megacurie Cave for Metallurgical Testing," Argonne National Laboratory, Lemont, Illinois.

Glen, H. M., "The Manipulator Hot Cells Above the Oak Ridge Research Reactor Pool," Oak Ridge National Laboratory, Oak Ridge, Tenn.

Bazire, M. R., et al., "A 10 Kilocuries Hot Laboratory in Saclay," Centre D'Etudes Nucleaires de Saclay, France.

Raggenbass, A., et al., "Radioactive Chemical Apparatus," Centre D'Etudes Nucleaires de Saclay, France.

Cherel, G., et al., "Equipment and Radio-Metallurgical Techniques in Saclay's Hot Laboratories," Centre D'Etudes Nucleaires de Saclay, France.

Detilleux, E., "The C.E.N.'s Hot Facilities," Centre D'Etudes Pour Les Applications de L'Energie Nucleaire, Brussels, Belgium.

Moll, Justus, Dr., "Some Ideas and Proposals Regarding Standardized Equipment for Hot Laboratories and Remote Control," Leybold-Hockvakuum-An Lagen, G.M.B.H., Koln-Bayental, Germany.

Isbin, H. S., et al., "The University of Minnesota Gamma Irradiation Facility," University of Minnesota, Institute of Technology, Minneapolis, Minnesota.

Anliot, R., "Description of a 19.5 Kilocurie Co^{60} Source and Hot Cell," Admiral Corporation, Chicago, Illinois.

Buehler, R. J., "Facility to Study the Effects of Radiation on Petroleum Processes and Products and the Application of Radioactive Material in the Petroleum Industry," Sinclair Research Laboratories, Inc., Harvey, Illinois.

Haaker, L. W., et al., "The Construction and Start-Up of a 100,000 Curie Co^{60} Irradiation Facility, "Nucledyne Corp., Cook Research Laboratory Division, Morton Grove, Illinois.

Ferguson, K. R., "A Survey of the Characteristics of Gamma Irradiation Facilities," Argonne National Laboratory, Lemont, Illinois.

Langlois, C. E., "The Design of the Idaho Expended Core Facility," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Pa.

Clayton, N. J., "Reactor Core and Fuel Element Handling and Disassembly in the ECF Water Pits," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Penn.

Stearns, R. F., et al., "Operating Experience with Zinc Bromide Shielding Windows at the Knolls Atomic Power Laboratory," General Electric Co., Knolls Atomic Power Laboratory, Schenectady, New York.

Bottenfield, B. F., "Remotely Cutting and Canning of Core Samples Obtained from Underground Nuclear Tests," Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Morand, R. F., "Portable Shielded Vehicle," General Electric Co., Aircraft Nuclear Propulsion Dept., Cincinnati, Ohio.

Blomgren, R. A., "A 10,000 Curie Co^{60} Irradiation Facility for Chemical Research," Argonne National Laboratory, Lemont, Illinois.

Ferguson, K. R., et al., "Coloration of Shielding Window Glasses," Argonne National Laboratory, Lemont, Illinois.

Plastino, G. G., "Clarification of Clouded Oil-Filled and Zinc-Bromide Shielded Windows," General Electric Co., Aircraft Nuclear Propulsion Dept., Cincinnati, Ohio.

Hare, A. W., et al., "Remote Metallography Practices at Battelle's Hot-Cell Facility," Battelle Memorial Institute, Columbus, Ohio.

Cain, F. M., et al., "Remote Metallographic Equipment and Practices," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Pennsylvania.

McCubbin, J. G., et al., "Micromanipulator for Use in a Remote Handling Cell," Atomic Energy of Canada Limited, Chalk River Project, Chalk River, Ontario, Canada.

Niebuhr, W. F., et al., "Impression Molding of Radioactive Elements," General Electric Co., Knolls Atomic Power Laboratory, Schenectady, New York.

Stratton, K., "Density Measurement Problems in Hot Cells," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Pa.

Deily, G. J., et al., "Primary 'Containment' for High Level Cave Experiments," Savannah River Laboratory, Aiken, South Carolina.

Youngquist, C. H., et al., "Hot Laboratory Problems in Isolating Gram Quantities of Transplutonium Elements," Argonne National Laboratory, Lemont, Illinois.

Brandt, R. L., et al., "Laboratory Equipment for the Collection of Fission Product Gasses from Irradiated Ceramic Fuel Elements," General Electric Co., Hanford Atomic Power Operation, Richland, Wash.

Stearns, E. H., "Modification to Master-Slaves at Bettis Hot Laboratory," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Pennsylvania.

Willey, M. G., "Remote Installation and Removal of Hot Cell Apparatus," Oak Ridge National Laboratory, Oak Ridge, Tenn.

(A movie), "EBR-I Core Disassembly After Meltdown," Argonne National Laboratory, Lemont, Illinois.

Durrill, D. C., "A Conducting Plastic for Metallographic Specimen Mounts," General Electric Co., Aircraft Nuclear Propulsion Dept., Cincinnati, Ohio.

Grazzini, E. D., "A Furnace for Elevated Temperature Tensile Testing," Westinghouse Electric Corporation, Atomic Power Division, Pittsburgh, Pa.

Stearns, R. F., et al., "A New Fuel Element Annealing Facility at Knolls Atomic Power Laboratory," General Electric Co., Knolls Atomic Power Laboratory, Schenectady, New York.

Maharam, A. L., "The Bettis Plant Radioactive Sample Corrosion Test Facility," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Pa.

Cunniff, C. E., "Evolution of Remote Milling Machines at Pratt-Whitney Aircraft Hot Cell Facility," Pratt & Whitney, East Hartford, Conn.

Crawford, C. A., et al., "Remote Controlled Lathe," Atomic Energy of Canada Limited, Chalk River Project, Chalk River, Ontario, Canada.

Stratton, K., "A Continuously Recording Micrometer - Profilometer for Hot Laboratory Application," Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Penn.

Morgan, J. R., et al., "Remote Metallographic Facility," General Electric Company, Vallecitos Atomic Laboratory, Pleasanton, California.

Wu, M. K., et al., "Contamination Control Procedures at Pratt-Whitney Aircraft Hot Cell Facility," Pratt & Whitney Aircraft, Division of United Aircraft Corp., East Hartford, Conn.

Beccasio, A. J., et al., "Decontamination Studies on Ceramic Products," Armour Research Foundation, Chicago, Illinois.

Altamari, L. A., et al., "Plutonium Irradiation," General Electric Co., Knolls Atomic Power Laboratory, Schenectady, New York.

Scotti, V. G., "Recovery of Gaseous Byproducts Employing Vacuum Techniques at Pratt-Whitney Aircraft Hot Cell Facility," Pratt & Whitney Aircraft, Division of United Aircraft Corp., East Hartford, Conn.

Pate, W. A., "Sampler and Filter Cartridge Changer Equipment for Radioactive Organic-Aqueous Streams," Oak Ridge National Laboratory, Oak Ridge, Tenn.

Trapp, W. C., "A Pneumatic Carrier for Irradiation of Materials in N. R. X. Reactor," Atomic Energy of Canada Limited, Chalk River, Ontario, Canada.

DuTemple, O. J., et al., "Design, Standardization, Fabrication, Cost and Sources of Plastic Glove Ports," Argonne National Laboratory, Lemont, Illinois.

Stout, E. L., et al., "Safety Considerations for Handling Plutonium," Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Hungerford, T. W., "Fire Protection in Radio Chemical Facilities," Oak Ridge National Laboratory, Oak Ridge, Tenn.

Smith, S. C., et al., "Hot Lab Safety," General Electric Co., Knolls Atomic Power Laboratory, Schenectady, New York.

Stang, L. G., Jr., "Some Safety Recommendations Pertinent to Hot Laboratories," Brookhaven National Laboratory, Upton, New York.

Hale, R. J., "Laboratory Ventilation," Savannah River Laboratory, E. I. duPont de Nemours & Co., Aiken, South Carolina.

Engle, P. M., "Review of High Efficiency Air Filters," Cambridge Filter Corp., Syracuse, New York.

NERB-33

A STUDY OF ECONOMICAL ASPECTS OF SMALL SCALE NUCLEAR POWER PLANTS, Nuclear Energy Research Bureau, New York 5, New York, April 16, 1956. 25 pp.

This report is one of a series of reports published by NERB which is a private bureau studying the economic effects of the new energy. This study explores the economics of small scale nuclear power plants. Included are the design aspect requirements and fundamental economics of small reactors. The analysis includes the economies of blankets, the requirements for power in isolated locations, the transportation problems of conventional fuels, etc.

The reactor programs of the U.S., Great Britain, France, and Russia are compared as known at this time.

NESC-ANL

Heineman A H (Group Leader)
CONTAINMENT FOR THE EBWR,
Argonne National Laboratory, Lemont, Ill. Published by The American Society of Mechanical Engineers for the 1957 Nuclear Engineering and Science Congress, 29 pp.

The philosophy and limitations for establishment of design parameters are presented for both containment of gaseous and particulate materials and containment of missiles, as well as means for preventing the launching of missiles, which might puncture the containment shell. The established parameters are stated, and the procedure which was followed in developing the final designs for both phases is delineated.

NESC-57-19

Rolan Gilbert and Hinrichs Charles
THE DEVELOPMENT OF A UNIVERSAL-TYPE CONTROL DRIVE MECHANISM FOR NUCLEAR REACTORS,
American Machining and Foundry Company, Greenwich, Conn. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 8 pp. (5 refs).

There are four major classes of research reactors operating in the United States, and within each class there are several different models. In most of these reactors, control rods, actuated by a drive mechanism, are used as safety and regulating devices. The drive mechanisms, although similar in principle, are different in design.

This paper describes the development of a universal-type drive mechanism now being used on, and adapted to, a variety of research and power reactors. This development, a significant step toward standardization in the nuclear reactor field, is described in terms of the different types of drives developed to date, an analysis of their differences and similarities, and the application of this analysis to the development of an electro-mechanical, universal-type, control rod drive mechanism.

NESC-57-33

Kanter J J
ON THE QUALITY REQUIREMENTS FOR STEEL VALVES FOR NUCLEAR POWER PLANTS,
Crane Co., Chicago, Ill. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 5 pp. (10 refs).

A statement is made covering the considerations and problems encountered in making available steel valves suitable for the peculiar conditions of nuclear power plants. The rigid inspection requirements for steel components, the extensive use of corrosion resistant steels, the problems of sealing, and the specifications for forgings and castings entering the procurement of the quality demanded from primary loop valves are discussed. The discussion on the choices of the stainless steels is valuable.

NESC-57-66

Anderson Kermit W and Dunning Donald N
ABSORBER MATERIALS FOR REACTOR CONTROL,
General Electric Co., Schenectady, New York. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 8 pp.

The control of reactors based on movable poisons is discussed. Discussion of materials using boron, hafnium, gadolinium, samarium, and europium indicates that gadolinium and europium are the most favorable materials.

The determination of the favorable materials is based on effectiveness of neutron capture, effectiveness over the spectrum, and availability of the material.

A discussion of the effects of the deterioration and one remedy--the use of oxides and the means of obtaining the dispersion necessary--is included.

47

NESC-57-74

Pomerance Herbert
REACTOR EXPERIMENTS IN ORSORT,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Published by the American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 4 pp.

Experiments with reactors may divulge information about the reactor, or they may use the reactor as a source of radiations. The ORSORT program uses two self-sustaining nuclear reactors and a subcritical reactor. The experiments reflect the availability of materials and reactor time at ORNL, along with the assessment of importance to experiments.

NESC-57-79

Hammitt Frederick G and Ohlgren Harold A
NUCLEAR POWERED GAS TURBINES FOR LIGHT WEIGHT POWER PLANTS,
University of Michigan, Ann Arbor, Michigan. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 26 pp. (10 refs).

The suitability of closed-cycle gas turbine power plants in combination with various types of nuclear reactors is examined. Typical examples of both a heterogeneous and a homogeneous reactor power plant are presented. Weight, cost, and performance are compared for various possible fluids over a range of temperature and pressure. Comparisons are made with alternative heat engine systems.

NESC-57-85

Beck Clifford K
THE WATER BOILER AS AN INSTRUCTIONAL TOOL,
U. S. Atomic Energy Commission, Washington 25, D. C. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 5 pp.

The "water boiler" type reactor, which operates at atmospheric pressure and power levels up to 50 kw, with highly enriched uranium in the water solution as the fuel, possesses a number of unique and advantageous features as an instructional tool. This report discusses its application as an instructional tool.

NESC-57-92

Jensen Emil C, et al.
PROBLEMS FACING STATE AGENCIES IN HANDLING TREATMENT AND DISPOSAL OF RADIOACTIVE WASTES,
Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 6 pp. (13 refs).

Inventory of problems, viewpoints, resources, and requirements of states relating to control of radioactive wastes and materials as sources of contamination of the environment and radiation exposure of the general public. Intended to serve as a basis for effective integration of related activity on control of radiation hazards.

NESC-57-93

Ullman J W and Arnold E D
DECAY AND STORAGE OF IRRADIATED FUEL,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 6 pp. (3 refs).

Reasons for storage, to allow decay of irradiated fuel elements, and possible methods of storage are given. The effects on storage and inventory costs of fuel element composition, plant size, element geometry, reactor type, methods of irradiation and recycle, and type of metallurgical handling are discussed. Estimates and comparisons are included for the decay for several typical fuels. The special problems associated with thorium fuel elements are considered.

NESC-57-98

Erwin Arthur F
PUMPS FOR NUCLEAR POWER PLANTS,
Allis Chalmers Manufacturing Co., Milwaukee, Wisconsin. Published by The American Society of Mechanical Engineers for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 11 pp.

This report is a tabulation and analysis of the requirements for the large special pump units used for coolant circulation in each of the major nuclear power plants and power demonstration projects now completed or under construction, and summarizes the estimates of future requirements for the quantities, types, and ratings of these special pump units which have been obtained from all available qualified sources. This information should be frequently helpful to reactor designers and engineers in selecting ratings for pump units that are already developed or that are within the range that can be reached by minor modification of existing pump units, to avoid the cost and delay of special development, and to avoid a source of trouble that may exist when no prototype tests of a new rating have been made.

NESC-57-108

Proctor Joseph H
APPLICABILITY OF CLAD STEELS TO HEAVY WATER PIPING,
Lukens Steel Company, Coatesville, Pa. Published by the American Society of Mechanical Engineers 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 7 pp. (2 refs).

This report is an evaluation of the applicability of clad steel in heavy wall piping. Clad steels made up of the following alloys (stainless steel, nickel, monel, inconel, and copper) bonded to a carbon steel backing were evaluated.

Tests were made to determine that clad could withstand service conditions of heat and pressure encountered in reactor operation.

Fabrication considerations were investigated and welding techniques proposed.

NP-6652

Winkler W
CLOSED-CYCLE GAS-TURBINE REACTOR POWER PLANT,
Reaktor AG., Switzerland, 15 pp. (17 refs).

The report is not intended as a preliminary design of a closed-cycle gas-turbine reactor power plant, but rather as a discussion of different problems involved with the development program of such a plant. First of all, we have to consider the type of enriched uranium fuel elements which permit an operation at temperatures of about 700°C and above. We shall discuss some of the development work done in this field by private industry of the United States of America. Second, we shall present investigations on the choice of the gas from the nuclear and thermodynamic points of view. We shall also speak about heat transfer and pressure loss problems for different gases and their mixtures. Third, we would like to show calculations about the gas activity due to neutron capture of the gas, neutron capture of the gas impurities, residual matter in the gas due to erosion or incomplete cleaning, and fission product leakage from the fuel element. Furthermore, we shall compare the thermal efficiency of different steam and gas cycles.

NPG-126

Kiefer W M, et al.
ENVIRONMENTAL FACTORS AT PROPOSED SITE OF DRESDEN GENERATING STATION OF COMMONWEALTH EDISON COMPANY,
Nuclear Power Group, Chicago, Illinois, June 15, 1955, 66 pp.

This document is a comprehensive study of the environmental factors of the proposed site. The land, nature of the subsoil, occupations, weather--all are treated with extreme detail.

NRL-4668

Peters C W, Joblonski F E and Young M P
NAVAL RESEARCH LABORATORY RESEARCH REACTOR - PART I. INSTRUMENTATION TESTS AT OAK RIDGE NATIONAL LABORATORY,
Naval Research Laboratory, Washington, D.C., January 23, 1956, 16 pp. (5 refs).

The NRL reactor instrumentation channels with two compensated ionization chambers and a multiple-plate safety chamber were taken to the Oak Ridge National Laboratory to be tested in a Bulk Shielding Reactor. The compensation and dynamic range characteristics and the sensitivities of the detectors were investigated. The performance of the logarithmic and linear recording channels under reactor operating conditions was observed. The equipment performed within the limits required for use in the NRL reactor.

NRL-4729

Bibbs E H, Vogt R H and Downer K W
NAVAL RESEARCH LABORATORY RESEARCH REACTOR - PART II. REACTIVITY MEASUREMENTS ON A GRAPHITE AND WATER-REFLECTED CORE,
Naval Research Laboratory, Washington, D. C., May 24, 1956, 28 pp. (6 refs).

A series of experiments was performed jointly by NRL and BNL on a mock-up of the NRL Research Reactor at the critical facility of Brookhaven National Laboratory. Reactivity effects of fuel, temperature, a hole in the graphite reflector, control rods, and movement of the core were investigated as well as critical masses and relative neutron fluxes.

The critical mass, as a function of position, was found as the core was gradually moved from a configuration in which three sides were graphite and three sides water-reflected to one which was nearly completely water-reflected. Fuel was added in increments of one or two fuel plates as the configuration was slowly changed, and the reactivity effect of the fuel was measured at each step. In this way, the reactivity change with change in configuration was determined in terms of fuel. By an extrapolation of the results, it is estimated that the reactivity of the fuel necessary to maintain criticality, when the core is moved from the configuration in which three sides are graphite and three sides water-reflected to one which is completely water-reflected, is 4.4%.

NRL-5025

Wall G F and Young M P
NAVAL RESEARCH LABORATORY RESEARCH REACTOR - PART III. AN EIGHT-DECADE LOGARITHMIC AMPLIFIER FOR NUCLEAR REACTOR INSTRUMENTATION,
Radiation Division, Nuclear Instrumentation Branch, Naval Research Laboratory, Washington, D. C., October 18, 1957, 12 pp. (2 refs).

The logarithmic amplifier developed at NRL has a dynamic range of eight decades of current (10^{-11} to 10^{-3} amperes), good accuracy, a high degree of stability with changes in heater voltages, and requires no range switching. The amplifier will give an output which is proportional to the logarithm of its input current, and the circuit employs a pentode as the logarithmic element. The amplifier has been used satisfactorily in a signal channel which provides power level and period information continuously for the NRL research reactor control system. Radiation detector current is fed directly to the control grid of the logarithmic element. A feedback amplifier holds the plate current constant by adjusting the screen grid voltage. The adjusted screen grid voltage is also used to drive a recorder directly. Although designed specifically for the NRL research reactor control system, the amplifier should find many uses in the field of nuclear instrumentation.

NYO-4849 ASTRA-200-E-11

Mallon R G, Saldick J and Gibbons R E
CONCEPTUAL DESIGN OF AN ADVANCED ENGINEERING TEST REACTOR,
Advanced Scientific Techniques Research Associates, Milford, Conn., Contract No. AT-(30-1)-1986, March 1, 1957, 124 pp.

This report describes a conceptual design for an advanced engineering test reactor. The reactor is a large graphite assembly penetrated by parallel Zircaloy tubes through which flows a heavy-water solution of uranyl sulfate. Reactor power is 220 megawatts.

Reactor test facilities include nine vertical through-holes having thermal flux greater than 1×10^{15}. The central through-hole is 12 inches square and has a thermal flux of 1.9×10^{15}. The reactor provides a favorable environment for high temperature tests.

Total cost of engineering and construction of the reactor and associated plant is estimated to be $30,000,000.

NYO-8500

APPLICATION OF DIGITAL TECHNIQUES TO REACTOR CONTROL SYSTEMS,
Ford Instrument Company, Division of Sperry Rand Corporation, Long Island City, New York, Contract No. AT-(30-1)-1969, February 4, 1957, 11 pp.

A survey of control systems revealed that increased reliability and decreased maintenance, elimination of maintenance and operating crew errors, and replacement of relays were, in the main, the kind of instrument improvement desired.

The feasibility of making a substitution of transistor for relay circuitry was determined by building up a substitute for the relay circuitry of the Oak Ridge Bulk Shielding Facility Reactor. The improvements are of significant importance in reducing time, the elimination of moving parts, and greatly reduced size improves flexibility. The method of analyzing the problem is also included.

NYO-8501

APPLICATION OF DIGITAL TECHNIQUES TO REACTOR CONTROL SYSTEMS,
Ford Instrument Company, Division of Sperry Rand Corporation, Long Island City, New York, Contract No. AT-(30-1)-1969, June 1, 1957, 35 pp.

A digital system to provide count rate and period information in the reactor start-up channel is described. A description of a control rod position indicator based upon an electromagnetic delay line principle is given. The conclusions reached were:

1. It appears feasible to measure rod position by translating it into a delay line of a pulse circuit.
2. There are commercially available components which can be used to monitor the change in delay time of this transmission line.
3. Because of the variables involved, both mechanical and electrical, an order of magnitude solution is the only one possible without resorting to an experimental program.

An alternate approach would read the time delay of the air-core portion of the transmission line. An analysis is given of advantages, problem areas, and feasibility for each design.

NYO-8502

APPLICATION OF DIGITAL TECHNIQUES TO REACTOR CONTROL SYSTEMS,
Ford Instrument Company, Division of Sperry Rand Corporation, Long Island City, New York, Contract No. AT-(30-1)-1969, October 17, 1957, 46 pp.

This is the third quarterly report submitted in connection with a study to investigate the application of digital techniques to reactor controls. Three specific applications have been studied during the period covered by this report. A system to utilize digital techniques for start-up control is discussed with emphasis on system approach, output display, size, weight, cost, and information on smoothing techniques. A breadboard design to establish feasibility of a rod position indicator system is described. This system utilizes an electromagnetic delay line principle. Two pressure-indicating schemes are described.

NYO-8503

DIGITAL ROD POSITION INDICATOR SYSTEM,
Ford Instrument Company, Long Island City, New York, Contract No. AT-(30-1)-1969, December 2, 1957, 21 pp.

The primary objective of this study is to develop an improved rod position indicator which permits the accurate measurement of a rod position in applications which preclude direct contact with rod or driving mechanisms, and penetration into the rod housing and control structure.

This report discusses the method of determining the position of a control rod through changes in inductance caused by changing position of the rod in an electrical coil. Experimental results of accuracy and dependability are included.

ORNL-167

Martin A B and Mann M M
CRITICAL EXPERIMENTS FOR THE HIGH FLUX REACTOR,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 22, 1948, 39 pp.

This report is the third of a series on criticality studies of small thermal reactors. While the earlier reports contained data from relatively simple and "clean" assemblies, the experiments to be described in the present paper involved assemblies which were less simple and less "clean." The term "clean" is used here to imply an experimental arrangement in which the core and reflector are not only of simple, calculable geometry, but are also as free as possible from holes, recesses, and extraneous materials.

ORNL-681

English James L
THE CORROSION OF 356 ALUMINUM IN SIMULATED COOLING WATER FOR THE PROPOSED MATERIALS TESTING REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, July 20, 1950, 107 pp.

A report is presented on the corrosion of 356 T-7 aluminum in simulated cooling water for the proposed Materials Testing Reactor. Stagnant and dynamic corrosion tests were conducted in demineralized water containing small amounts of hydrogen peroxide at a pH range of 5.5 to 6.5 and a temperature of 85°C. Corrosion behavior of the uncoupled alloy was investigated as well as its galvanic corrosion behavior with 2S aluminum, 43 aluminum, extruded beryllium, and 347 stainless steel. Sodium chromate and sodium dichromate were tested as possible corrosion inhibitors.

The corrosion characteristics of 356 aluminum are greatly influenced by oxygen concentration, pH, and contact with dissimilar metals. Heat treatment of the alloy affected the corrosion resistance slightly; cast aluminum showed a slightly superior corrosion resistance to the heat-treated alloy. Corrosion attack on the alloy at 90°C was of similar magnitude as an attack at 30°C; maximum corrosion attack occurred at 50°C. Stagnant versus dynamic test results indicated that pitting intensity was reduced under dynamic conditions, but the general corrosion rate was increased. Corrosion attack generally increased as the hydrogen peroxide concentration increased from 0.0005 M to 0.005 M. Galvanic corrosion attack on the alloy was most severe when coupled to 347 stainless steel. Sodium chromate in concentration of 10 ppm was effective for reducing corrosion attack. A general observation of all test results indicated that an incubation period of 500 to 700 hours was required for the formation of the protective hydrated aluminum oxide film.

The average over-all stagnant corrosion rate for 356 aluminum in deaerated water, 0.0005 M and 0.005 M hydrogen peroxide solutions for 1008 hours was 0.007 mil/month; the average dynamic corrosion rate for similar conditions was 0.067 mil/month. In deaerated water, the presence of 10 ppm of sodium chromate resulted in negligible corrosion rates; in waters containing 0.0005 M and 0.005 M hydrogen peroxide concentrations, the average corrosion rate was 0.020 mil/month with almost complete elimination of pitting attack.

Galvanic corrosion of 356 aluminum in contact with 2S aluminum, 43 aluminum, extruded beryllium, and 347 stainless steel in deaerated water, 0.0005 M hydrogen peroxide, and 0.005 M hydrogen peroxide solutions, averaged 0.013, 0.010, 0.025, and 0.355 mil/month for 1008 hours exposure, respectively. With 5 to 10 ppm of sodium chromate in the test solutions, these corrosion rates were reduced to 0.007 mil/month in contact with 2S aluminum, 0.001 mil/month in contact with extruded beryllium, and 0.007 mil/month in contact with 347 stainless steel. The maximum pit depth encountered on stagnant 356 aluminum test specimens was 16.4 mils in 1008 hours; for dynamic test conditions, the maximum pit depth encountered was 8.0 mils for the safe time.

ORNL-692

Beall S E
PROCEDURE FOR ERECTION OF THE MATERIALS TESTING REACTOR MOCK-UP,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 18, 1950, 33 pp.

Early in 1947 the decision was made to erect a full-scale prototype of the Materials Testing Reactor (MTR) tank with its internal components and a simple water system.

This report describes the stepwise assembly procedure of all reactor parts exclusive of the structure and water system, which have little in common with the MTR. The procedure was based on "Operations and Procedure Schedule for Erection of Pile Mock-Up," written by F. C. Zapp, dated February 4, 1949.

ORNL-991

Breazeale W M
THE NEW BULK SHIELDING FACILITY AT OAK RIDGE NATIONAL LABORATORY,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 8, 1951, 54 pp, (10 refs).

The Bulk Shielding Facility at ORNL is described in detail. This swimming pool-type reactor was planned to attenuate measurements on bulk samples as well as to test mock-ups of practical shields and to provide a leakage flux of about 10^{11} n/cm^2-sec. Two features are the movable nature of the reactor in the pool and a gate provision so that part of the tank can be emptied for various buildup features. A formula for removable concrete blocks which have good neutron and gamma attenuating properties is given. Reactor core design control and safety circuitry and instrument ion corrosion and critical experiments are discussed.

A list of drawings is included.

ORNL-1027

Meem J L and Johnson E B
DETERMINATION OF THE POWER OF THE SHIELD-TESTING REACTOR - I. NEUTRON FLUX MEASUREMENTS IN THE WATER-REFLECTED REACTOR,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 13, 1951, 32 pp. (6 refs).

The reactor at the Bulk Shielding Facility is being used as a source of neutrons and gamma rays for shielding experiments. The procedure is to erect shielding samples in front of the reactor and measure the attenuation of these neutrons and gamma rays through the shield. Since the reactor can be operated at various power levels, all shielding measurements are normalized to a power level of 1 watt. It is immediately obvious that some calibration of the power of the reactor is required. It is also necessary to know the flux leaking from the reactor when making shielding measurements. The leakage flux may be changed when a different shielding sample is placed next to the reactor depending on the characteristics of the shielding sample as a reflector. The determination of this leakage then becomes a part of the particular shielding experiment underway and is not considered further in this report.

ORNL-1139

Cole T E, St. John E E and Hanauer S H
THE MTR SAFETY SYSTEM AND ITS COMPONENTS,
Reactor Controls Department, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., April 4, 1952, 31 pp. (21 refs).

The safety requirements of the MTR are discussed, together with the devices built to meet these requirements. Three level and two period safety channels feed signals to a central control bus whose voltage in turn controls the current through electromagnets. The shim-safety rods suspended from these magnets fall into the reactor fast enough to catch the shortest expected period. The details of the various components used are discussed and the performance data are presented.

ORNL-1537

Meem J L, Holland L B and McCammon G M
DETERMINATION OF THE POWER OF THE BULK SHIELDING REACTOR - PART III. MEASUREMENT OF THE ENERGY RELEASED PER FISSION,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, March 11, 1954, 80 pp. (7 refs).

The energy released per fission was measured in the Bulk Shielding Reactor using a specially constructed fuel element. The special element had a removable center fuel plate from which discs were punched to facilitate measurement of their activation by exposure in the reactor. A similar uranium-bearing disc was activated by exposure in a known neutron flux. By comparison, the actual fission rate in the special fuel element was determined.

The special element was equipped with water tubes at top and bottom through which water was pumped at a known rate. Thermocouples were used to measure the temperature rise across the fuel element, special precautions being taken to prevent heat leakage. The power, or rate of energy, as a comparison with the fission rate gave the heat released per fission in the special element. The net amount of radiation leaking out of the fuel element (less than 0.2%) was calculated as a correction to this figure.

The energy per fission in the reactor was 193 ± 5 Mev. The parasitic capture in the Bulk Shielding Reactor is calculated to be 2.7 Mev. Accordingly, the energy released per fission (exclusive of neutrino energy) is 190 ± 5 Mev.

ORNL-1642 (Del.)

Briggs R B
AQUEOUS HOMOGENEOUS REACTORS FOR PRODUCING CENTRAL-STATION POWER,
Reactor Experimental Engineering Div., Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 25, 1951, 96 pp. (56 refs).

Aqueous homogeneous reactors are examined from the standpoint of producing central-station power. Included are the materials requirements for a large power industry, a review of raw materials supplies, a status report on the technology of aqueous homogeneous systems, and a comparison of one- and two-region reactors that use thorium and uranium fuels.

ORNL-1790

Bohannon J R
COST STUDY OF A POWER INCREASE FOR THE BULK SHIELDING REACTOR,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, June 24, 1958, 42 pp.

It is known that the Bulk Shielding Reactor can be operated at higher powers than the present 100-kw level since the similar Materials Testing Reactor and Low Intensity Test Reactor are operated at 30 and 3 megawatts, respectively. The fuel elements, coolant, and moderator of all three reactors are fundamentally the same; therefore, only the type of cooling system to be employed for a higher power level of the BSR must be decided upon. This report presents a cost study of three cooling systems: (1) a free convection cooling system, the system now used; (2) a pump-forced convection cooling system with a one-pass flow of water through the elements; and (3) a pump-forced convection cooling system with a three-pass flow of water through the elements. The third system is effected by passing water successively through three parallel regions of the element. The range of power levels considered is 1 to 10 megawatts. On the basis of this study, it was found that a 2.5 to 2.8 megawatt power level with free convection cooling would be possible for $15,200 while the cost of the one-pass-flow, cooling, pump-forced convection system for 10 megawatts would be $180,000. Costs of the free convection and one-pass-flow, pump-forced convection systems for various power levels are quoted with a recommendation that the strongest consideration be given to the free convection cooling system.

ORNL-1894

Welton T A
A STABILITY CRITERION FOR REACTOR SYSTEMS,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, July 7, 1955, 17 pp.

This report presents a discussion of stability in a reactor system. The system is described by a differential equation. Reactor system means a reactor coupled to its heat-removal system and a reactivity control system. Four effects that could influence the stability are discussed: (1) thermal, (2) relaxation, (3) flow effects, and (4) time lag effects from coolant flow and time lag effects from the inertia of a heated fluid which must be accelerated.

ORNL-1935

Maienschein F C, Henry K M and Johnson E B
A HAZARDS REPORT FOR THE WADC VOID MOCK-UP TEST AT THE BULK SHIELDING FACILITY,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 1, 1955, 10 pp. (1 ref).

This report discusses void effects on reactivity in the event of a void collapse. This study was primarily initiated because of the large voids designed for the WADC reactor.

ORNL-1987 CF-54-10-76

Chapman R H
ANALYSIS OF SPHERICAL PRESSURE VESSEL HAVING AN ENERGY SOURCE WITHIN THE WALL,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 26, 1954, 111 pp. (17 refs).

A method is given for determining the optimum thickness of a spherical pressure vessel in which there is an exponential heat source contained within the vessel wall. The method has applications in the design of certain types of nuclear reactors. It is shown how the thermal stress may be estimated for thermal reactors and combined with pressure stress to obtain the total stress. The solution to a hypothetical design problem is given to illustrate the procedure. Some data are included which should be an aid in the solution to similar problems.

ORNL-2018

Maienshein F C and Henry K M
OPERATING PROCEDURES FOR THE BATH SHIELDING FACILITY,
Applied Nuclear Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 2, 1956, 13 pp.

This is the third edition of the operating procedure for the BSF, and discusses startup and steady operation, reactor loadings, reactor startup check lists, location of Scram buttons, emergency operating procedure, and control and safety tests.

ORNL-2057 (Del.)

McDuffie H F and Hill V K
HOMOGENEOUS REACTOR PROJECT QUARTERLY PROGRESS REPORT FOR THE PERIOD ENDING JANUARY 31, 1956,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April 17, 1957, 141 pp.

This quarterly progress report indicates some of the problems in procuring and installing a homogeneous reactor. Some of the topics of interest are procedures for placing barytes aggregate, pump modifications, the fuel processing plant, the attack of ThO_2 slurries on stainless steel was correlated with particle size, velocity of the slurry, oxygen concentration, room temperature pH, ThO_2 concentration, and ThO_2 calcination temperature. A comparison of corrosion resistance of typical spring materials, isoelastic and elgeloy, indicates the latter to be the superior material. A number of other materials were studied for corrosion resistance: platinum, gold, Zircaloy 2, titanium and 347 stainless steel.

Metallographic identification of location of hydrides was developed which indicated that the hydride forms in the grain boundaries of the zirconium alloys and within the grains in crystal-bar zirconium. A system for welding titanium in air uses an inert gas atmosphere and an internal purging gas. Fully austenitic welds for 347 stainless steel have tentatively been devised. Chemistry research on the alkali metal carbonate-uranium trioxide system, the quarternary systems $CuO-UO_3-SO_3-H_2O$ and $NiO-UO_3-SO_3-H_2O$, were studied.

ORNL-2081-1

Henry K M, et al.
CRITICAL EXPERIMENTS AT THE BSF,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 9 pp.

Critical experiments were performed at the BSF with the 20% enriched elements for the swimming-pool-type Aquarium Reactor prior to their shipment to Geneva. The total amount of U^{235} in the critical loading was 3660.9 g, but the excess reactivity was not determined. Similar experiments were performed with the highly enriched (~89%) elements for the Pennsylvania State University Reactor. The reactor was critical with 2914 g of U^{235} and an excess reactivity of ~1%. In addition, several critical experiments were performed by ORSORT students as part of their laboratory class. The effect on the reactivity of slowly flooding a large air-filled void adjacent to the BSR was investigated; the largest change observed was +2.62% $\Delta k/k$. A series of experiments to determine the effect of introducing voids within the core was also performed.

ORNL-2081-2

Henry K M, et al.
EFFECT OF THE REFLECTOR ON THE NEUTRON FLUX IN AN ORR BEAM HOLE MOCKUP,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 8 pp.

An experiment with the BSR has shown that the thermal-neutron flux leakage into a beam tube adjacent to the reactor could be appreciably increased by substituting heavy water for the light-water reflector immediately surrounding the beam tube. The experiment was motivated by the interest in increasing the flux in beam holes adjacent to the Oak Ridge Research Reactor, and several configurations were tested.

ORNL-2081-3

Henry K M and Anno J N
SENSORY INSTRUMENTATION STUDIES FOR THE BSR,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

A series of experiments have been performed to check the saturation properties and linearity of response of the ionization chambers which supply the basic signals for control and power-level indication of the BSR. It was found that the saturation properties of the log N chamber, which actuates the log reactor power indicator, recorder, period meter, and period scram circuit, have changed no more than about 0.4% since its initial installation. The investigation of the response of the fission chamber and galvanometer chamber indicates that for power demands of 100 kw, 500 kw, and 1 Mw, the actual power sags approximately 2, 10, and 16%, respectively.

ORNL-2081-4

Henry K M and Anno J N
TEMPERATURE DISTRIBUTION IN THE BSR UNDER NATURAL CONVECTION COOLING,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 7 pp.

Measurements of the temperature distribution on the surface and in the core of BSR fuel plates have been made to provide information on: (1) the rate of temperature rise within the core, the knowledge of which will facilitate the design of similar reactors; and (2) the power at which boiling would first occur. The measurements also provide experimental evidence for heat transfer and nuclear calculations. Extrapolation of the data from the surface measurements indicates that boiling would first occur in the reactor at a power of approximately 2100 kw.

ORNL-2081-5

Flynn J D
WATER PURIFICATION AND CIRCULATION SYSTEMS AT THE BSF,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

Two water purifying loops for the demineralized water of the reactor pool have been installed at the BSF. One system removes suspended particles from the water, and another system maintains a 250,000- to 350,000-ohm/cm specific resistance of the pool water. A set of jets has also been installed above the BSR in order to diffuse the activated water for a sufficient length of time to suppress the N^{16} activity at the pool surface. With the jets in operation and the reactor at a power of 1 Mw, the radiation 19-1/2 in. above the 17-1/2 ft of water directly over the reactor is reduced from 800 to 32 mr/hr.

ORNL-2081-6

Champion W R
AIR ACTIVITY PRODUCED BY THE BSR,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

Since the air-borne, gamma-ray activity measured 40 ft from the BSR was an appreciable fraction of the tolerance level, an experiment was performed to determine the origin of the activity. Sources of activity were collected from the air above the pool surface and from the pool water 6 in. above the reactor, and an examination was made of their energy spectra and the time-decay characteristics. The half lives of several prominent peaks were observed, but comparison with published data has failed to result in any definite assignments other than N^{16}.

ORNL-2081-8

Silver E G
CALCULATION OF THE EFFECT ON REACTIVITY WHEN HEAVY WATER IS ADDED TO A LIGHT-WATER-MODERATED REACTOR,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

A calculation of the effect on the reactivity of adding D_2O in various proportions to the moderator of H_2O-moderated reactors has been made. Plots of $k_{(H_2O + D_2O)}/k_{H_2O}$ as a function of the volume fraction of D_2O in the moderator are presented for all combinations of several values of the macroscopic total absorption cross section of the uranium in the core $\left(\sum_{\alpha}^{\text{fuel}}\right)$, the ratio of the volume fraction of metal in the core to the volume

fraction of the moderator (M/W), and the buckling (B^2). The values used were $\sum_a^{fuel}$ = 0.03, 0.052, and 0.07 cm^{-1}, M/W = 0.5, 0.733, and 1.0, and B^2 = 0.01, 0.007, 0.004, and 0.001.

ORNL-2081-9

Silver E G
COMPARISON OF CALCULATED CRITICAL MASS OF THE BSR WITH EXPERIMENT, Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956. 12 pp.

The critical masses of three swimming-pool-type reactors have been computed and compared with corresponding experimental critical masses for the specified loadings in the BSR. Two reactor codes were employed in the calculations: the UNIVAC Eyewash 30-group code using three concentric spherical regions (control rod, fuel, and reflector), and the Oracle three-group, three-region code. The latter was used both as a two-region and as a three-region problem for a cylindrical or spherical reactor. The calculations with the best assumptions gave results that were within 1% of the experimental critical mass and within 0.4% of the reactivity.

ORNL-2081-10

Fox J K and Gilley L W
CRITICAL EXPERIMENTS WITH AQUEOUS SOLUTIONS OF U^{235}, Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 8 pp.

A number of experiments have been performed to determine the critical conditions for vessels containing highly enriched (~90%) uranium in water solutions of UO_2F_2. It was found that, for solutions contained in cylinders, 8.76 in. is very near the diameter of an infinitely high, unreflected aluminum cylinder; 8.5 to 9 in. is the corresponding diameter for stainless-steel cylinders.

The effect of interacting arrays of 6- and 8-in. diameter cylinders containing a solution with an $H:U^{235}$ atomic ratio of 44.3 was also investigated for various reflector conditions and edge-to-edge spacings. The critical height of water-reflected arrays of 6-in. diameter cylinders approaches the value of a single cylinder at an edge-to-edge spacing of about 15 in. When the cylinders are wrapped in cadmium sheets, the infinite critical height would be for a spacing of 2 in. The critical height of water-reflected arrays of 8-in. diameter cylinders approaches the value of an edge-to-edge spacing of approximately 9 in. A single cadmium-wrapped 8-in. diameter water-reflected cylinder becomes critical, and the values of the critical heights of arrays of cadmium-wrapped 8-in. diameter cylinders approach the value for the single cylinder. Three unreflected 8-in. diameter cylinders would become critical with infinite height at about a 9-in. edge-to-edge spacing, while seven cylinders would require an 18-in. spacing.

The relative effects of water, furfural, concrete, graphite, and firebrick as neutron reflectors for solutions contained in aluminum cylinders were also investigated.

ORNL-2081-11

Zimmerman E L
TWO BERYLLIUM-MODERATED CRITICAL ASSEMBLIES,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 9 pp.

Two unreflected beryllium-moderated critical assemblies have been built in a simple geometry in order to check the critical parameters predicted for them by multigroup reactor calculational methods. The assemblies, designated as CA-1 and CA-18, had regular lattices of 10-mil-thick enriched uranium metal fuel disks separated by 1- and 4-in. blocks of beryllium metal, respectively. Assembly CA-1 had outside dimensions of 21 x 21 x 23.2 in. and was critical with a U^{235} mass of 18.08 kg; the withdrawal of one control rod was equal to 0.0054 in reactivity. Assembly CA-18 had outside dimensions of 24 x 28.4 x 24.1 in. and was critical with 7.65 kg of U^{235}; the control-rod withdrawal was equal to 0.0020 in. reactivity. Only the experimental data are presented, the correlation with theory having been published elsewhere.

ORNL-2081-14

Gwin R
DETERMINATION OF REACTOR PARAMETERS FROM PERIOD MEASUREMENTS,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

Measurements of a static critical mass as well as reactor period for off-critical conditions can be used to determine the effective delayed neutron fraction, and from this the age of prompt and delayed neutrons can be estimated by age theory. From data on a dilute aqueous solution of U^{235} in a cylindrical container, the age of prompt neutrons has been estimated to be 25.4 cm^2. For delayed neutrons the age was estimated to be 14.1 cm^2; the effective delayed neutron fraction being 0.0096. Probable errors for these values have not been estimated.

ORNL-2081-15

Prohammer F G
COMPARISON OF ONE-DIMENSIONAL CRITICAL MASS COMPUTATIONS WITH EXPERIMENTS FOR COMPLETELY REFLECTED REACTORS,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

Critical-mass calculations for completely reflected cylindrical reactors would be greatly facilitated if a one-dimensional computational program used for spherical reactors could be applied. A comparison of cylindrical and spherical reactors has shown that the cylindrical reactors can be converted to equivalent spheres by a relationship which assumes that the buckling of a sphere is equal to that of the cylinder, making allowance for reflector savings δ. The relationship is expressed as

$$\frac{\pi}{R+\delta} = \left[\left(\frac{2.4048}{r+\delta}\right)^2 + \left(\frac{\pi}{b+2\delta}\right)^2\right]^{1/2}$$

where R and r are the radii of the sphere and cylinder, respectively, and b is the cylinder height.

ORNL-2081-37

Blosser T V, et al.
STUDY OF NUCLEAR AND PHYSICAL PROPERTIES OF THE ORNL GRAPHITE REACTOR SHIELD,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

The structural and nuclear durability of the 7-ft-thick concrete shield around the ORNL Graphite Reactor has been investigated. The results of the gamma-ray and neutron attenuation measurements are presented.

ORNL-2081-39

Otis D R
NEW LID TANK SHIELDING FACILITY SOURCE PLATE,
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

The source at the LTSF consists of a plate containing U^{235}, which absorbs thermal neutrons that issue from a hole in the ORNL Graphite Reactor shield. In September 1955, a new source plate (SP-2), that has several advantages over the old one (SP-1), was installed. The power of SP-2 is 5.18 ± 0.26 w, with a unit source strength of 1.30×10^{-2} w/cm^2.

ORNL-2081-40

Smolen J
DETERMINATION OF THE EFFECTIVE POWER OF THE OLD LID TANK SOURCE PLATE (SP-1),
Applied Nuclear Physics Division Annual Report for period ending September 10, 1956, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., November 20, 1956, 3 pp.

After installation of the new source plate (SP-2) at the LTSF, the power of the old source plate (SP-1) was determined by multiplying the power of SP-2 by a neutron leakage factor and dividing by an effective power ratio of the two plates. The results indicated a power of 1.7 w ± 11%.

ORNL-2086

Binford F T and Burnett T H J
A METHOD FOR THE DISPOSAL OF VOLATILE FISSION PRODUCTS FROM AN ACCIDENT IN THE OAK RIDGE RESEARCH REACTOR,
Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 9, 1956, 8 pp. (8 refs).

The Oak Ridge Research Reactor is a full enriched, heterogeneous, light-water-moderated and cooled beryllium-reflected reactor of the MTR-BSF type. It is designed to operate at a power level of 20 to 30 megawatts with a thermal-neutron flux of the order of 10^{14}.

In this paper the maximum credible accident is postulated to be that situation in which the reactor suffers from a deficiency in cooling capacity sufficient to cause melting of the fuel elements and subsequent release into the building of all the volatile fission products.

It is shown that, with properly engineered ventilating and gas-scrubbing equipment, the radioactive gas can be disposed of in such a way as to prevent harmful exposure to persons in the surrounding area. Direct radiation from the large mass of gas initially present in the building will be extremely intense in the immediate vicinity of the building. It is possible, however, through the use of a suitable alarm system, to evacuate this area in a time short enough to prevent serious overexposure to personnel.

ORNL-2091

Beall S E
CONTAINMENT PROBLEMS IN AQUEOUS HOMOGENEOUS REACTOR SYSTEMS,
Reactor Experimental Engineering Div., Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 9, 1956, 13 pp. (refs).

Containment problems in homogeneous reactors are discussed, with particular emphasis given to the manner in which they have been solved for the HRT. Bases for rigid leakage specifications on reactor components are explained. The design of the reactor enclosure is reviewed with respect to allowable leakage, as well as protection against fragments and internal pressures resulting from a reactor catastrophe.

ORNL-2148(Del)

Briggs R B (Project Director)
HOMOGENEOUS REACTOR PROJECT QUARTERLY PROGRESS REPORT FOR PERIOD ENDING JULY 31, 1956,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 3, 1956, 145 pp.

This document covers the progress of the homogeneous reactor project during the quarter from April 30, 1956 through July 31, 1956. Work on the project is broken down into seven areas each of which is reported in this document.

I. Homogeneous Reactor Test

Tests on reactor components were completed during the quarter as were preparations for a series of dump tests of enriched uranyl-sulphate at design pressures and temperatures. Modifications were made to the refrigeration system and the freeze jackets. Designs of the replacement pressure vessel were completed. Development continued on fuel and blanket pumps and improvements were made in valve and sampling equipment. The HRT ran a total of 1730 hours during the quarter with few difficulties. Modifications to the instrumentation include equipment in the area monitoring system, metering stations, liquid level indicators, and valves and operators.

The HRT fuel processing plants proceeded to work on the removal of fission products centrifugally. This included development of tools and equipment for remote removal of plugs and the hydroclone.

II. Reactor Design and Analysis

A feasibility study on a circulating fuel, aqueous, homogeneous research reactor was completed. Calculations concerning the effects of xenon transients on homogeneous reactor behavior were made. The Oracle code for calculating heat generation in materials due to gamma-ray absorption was used to calculate gamma heating in iron, lead, and aluminum samples placed near the Bulk Shielding Facility.

III. Engineering Development

Work on fuel systems proved the use of titanium and zirconium to be unsuitable for such applications, and conversion to 309 stainless steel is being considered for the test loop. The equipment for handling the thorium oxide in the blanket system functioned throughout the quarter, although one loop was shut down because the slurry solidified. A heated thermocouple-type liquid level indicator was fabricated and work was done on bellows for use in the uranyl-sulfate systems.

IV. Corrosion and Materials

Corrosion studies involving uranyl-nitrate and uranyl-sulfate solutions were continued to find the effects of these materials upon aluminum oxide, zircaloy, stainless steel, and titanium. Further tests involving uranyl fluoride were started.

Several water runs and an attempted slurry run on the experimental in-pile slurry loop are described. Studies of thorium-oxide slurries circulated in toroids indicated some correlation between particle size and attack rate on stainless steel.

The fabrication and testing of all titanium in-pile loops for radiation corrosion tests were completed. In addition to materials mentioned above, radiation corrosion effects on Incoloy, synthetic sapphire, platinum, and nickel were partially determined.

Considerable metallurgical work was performed during the quarter on the materials above. Major attention was devoted to welding in various titaniums.

V. Chemical Engineering Development

Chemical engineering work during the quarter was confined to fuel processing, plutonium producing, blanket processing, development in the thorium-oxide slurry characteristics, and chemical decontamination of activated equipment.

VI. Supporting Chemical Research

Studies of aqueous systems at elevated temperatures were continued during the quarter. Radiation studies of thorium-nitrate solutions proved mainly that the off-gassing which yields N_2 is temperature independent. Several techniques were developed in the field of analytical chemistry. These included improved titration techniques, improved techniques for determination of fluoride, aluminum and halides in thorium oxide. Work on reaction rates continued. Some radiochemical techniques were developed and improvements in spectrophotometric use were made. Extraction of protactinium-231 reached 1 gram during the quarter.

ORNL-2225

Beaver R J, Waugh R C and Leitten C F
SPECIFICATIONS FOR ARMY PACKAGE POWER REACTOR (APPR-1) FUEL AND CONTROL ROD COMPONENTS,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, August 7, 1957, 37 pp.

Final specifications are presented on the stainless-steel fuel and control rod components developed for service in the 10 megawatt Army Package Power Reactor, a heterogeneous, pressurized-water unit designed for producing power in remote locations. The specifications cover design and material requirements as well as the fabrication procedures developed and adopted for manufacturing the extended-life fuel element and the enriched boron-10 absorber section of the control rod. Included in the procedural specifications are methods for preparing uranium dioxide, boron carbide, stainless-steel ceramet cores and techniques for roll-bonding this material into composite stainless-steel plates; procedures are also described for manufacturing the absorber sections of the control rod. The procedural specifications are specific for manufacturing these components at ORNL, and merely represent a detailed guide in the event other fuel element fabricators are requested to furnish additional fuel elements and absorber sections.

ORNL-2240

Cole T E and Gill J P
THE OAK RIDGE NATIONAL LABORATORY RESEARCH REACTOR (ORR),
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, February 8, 1957, 55 pp. (17 refs).

The proposed ORNL Research Reactor is designed to serve as a general purpose research tool delivering an average thermal-neutron flux of 1.3×10^{14} n/cm^2-sec at the initial power level of 20 megawatts. Operation at power levels up to 30 megawatts is proposed for such times as sufficient cooling capacity is available to handle the increased heat load.

The reactor will use MTR-type fuel elements and beryllium reflector pieces in a 7 x 9 grid with moderation and cooling provided by forced circulation of demineralized water. The reactor tank is submerged in a pool filled with water with walls and bottom of barytes concrete which serves as a biological shield. Experimental facilities include two "Engineering Test Facilities" approximately 19 x 25 in. and six 6 in. diameter beam holes. In addition, access to the core is available through the water of the pool.

ORNL-2311

Moeller D W
ANALYTICAL CHEMISTRY DIVISION,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, July 2, 1957, 161 pp. (33 refs).

The purpose of this work was to study, in detail, a reactor cooling system of the recirculating type. Principle objectives of the study were identification of the radioactive nuclides present in the water at various stages in the system, determination of the source of these nuclides, and measurement of the efficiency of ion exchange beds in their removal.

Supplemental objectives of the study included evaluation of neutron activation techniques as applied to water and evaluation of gamma scintillation spectrometric techniques in the qualitative and semiquantitative determination of radionuclides in water.

This study was performed using the LITR at Oak Ridge. In addition to a description of the recirculating system of the LITR, this report includes information on analytical techniques and dissolved gas analysis.

ORNL-2312

Beaver R J, et al.
INVESTIGATION OF THE FACTORS AFFECTING SENSITIZATION OF ARMY PACKAGE POWER REACTOR (APPR-1) FUEL ELEMENTS,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 8, 1957, 20 pp.

Results are presented of the investigation necessitated by the unexpected intergranular attack of the Type 304L stainless-steel cladding in the Army Package Power Reactor (APPR-1) fuel plates after a flatten-annealing heat treatment and subsequent cleaning in 15% HNO_3-5% HF aqueous solution.

This fuel plate consists of a powder-metallurgy-prepared core containing 26 wt % UO_2 and 0.14 wt % B_4C in a Type 304B stainless-steel matrix. After the core is fabricated into a composite fuel plate, it is 20 mils thick and is clad with 5 mils of Type 304L stainless steel.

The data accumulated permit an evaluation of the material specified for APPR-1 fuel plates with relation to the effect of the manufacturing heat treatments on carburization and sensitization of the Type 304L stainless-steel cladding. The effect of the substitution of Type 347 stainless steel is also described. It is concluded that carbon diffusion from the Type 304B fuel-core matrix increases the carbon level of the Type 304L stainless-steel cladding during the manufacturing heat treatments. The cladding is then susceptible to sensitization during the heat treatments and is subject to intergranular attack in a reducing acid. It was further concluded that substitution of Type 347 stainless steel as the matrix material in the fuel core and the cladding, or as the cladding material only, would permit the fuel plates to be fabricated in accordance with the established APPR-1 manufacturing procedures without resulting in sensitization of the plate cladding.

ORNL-2313

Rosenthal M W, Tobias M and Fowler T B
FUEL COSTS IN SPHERICAL SLURRY REACTORS,
Reactor Experimental Engineering Div., Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, September 27, 1957, 42 pp. (10 refs).

Fuel costs have been obtained for two-region aqueous homogeneous reactors containing $U^{233}O_3$-ThO_2-D_2O slurry in both core and blanket regions. For comparison, costs were also computed for one-region slurry reactors and for two-region systems having no thorium in the core.

The major design variables were core diameter, blanket thickness, thorium concentrations in core and blanket, U^{233} concentration in blanket, and poison fraction in core. In the computations, isotope concentrations were established by means of equilibrium isotope equations. The critical fuel concentration was obtained by using a two-group, two-region reactor model. Charges for chemical processing by a Thorex plant were estimated with the aid of a simplified cost equation.

This study differs from earlier work in the use of a 4% inventory charge and an η for U^{233} equal to 2.25 (rather than 12% and 2.32), as well as in the presence of slurry in the core.

Over a wide range, fuel costs were found to be largely insensitive to variations in the design and operating conditions. There appears to be no decisive difference in fuel costs between solution-core and slurry-core systems; breeding gain, however, is improved by the use of slurry in the core. For two-region systems, fuel costs are as low as 1.2 mil/kwhr; for one-region systems they are at least 0.5 mil/kwhr higher.

ORNL-2318

Green F P (Editor)
REACTOR SAFETY SYSTEM RESPONSE,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, February 14, 1958, 101 pp. (4 refs).

Reactor accidents are discussed which might be caused by failure of the control system and which might be eliminated by better controls design. A second group of accidents, not caused by controls, and which therefore cannot be eliminated by better controls design, can be mitigated by a fast safety system. Factors are enumerated which govern the realization of a fast safety system. The swimming-pool reactor is used as an example.

ORNL-2329

Pare' V K and Visner Sidney
EXPERIMENTS ON THE KINETICS OF THE HRE,
(HRE - Homogeneous Reactor Experiment), Reactor Experimental Engineering Div., Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 8, 1957, 34 pp. (11 refs).

Reactivity was added at rates up to 0.7% per second at initial power levels from 1 watt to 20 kw, and the transient power behavior was observed. Reactivity was increased by various means: control rods, reflector level, fuel concentration, and fuel temperature. The experiments were performed to check theoretical safety calculations which predicted that the reactor would be self-stabilizing and capable of absorbing large introductions of reactivity. The power level rose to a peak for each reactivity excursion, in some cases several times higher than the rated power of 1 Mw, but decreased rapidly to an equilibrium value determined by the rate of increase of reactivity. For the most violent experiment, in which cold fuel from the heat exchanger was injected into the core, a peak power of 11 Mw was observed with a shortest period of 35 msec. The peak powers are in reasonable agreement with calculations in which a solution of the kinetic equations with the temperature coefficient of reactivity neglected (valid at low power) is joined to a solution in which the delayed neutrons are neglected (valid when prompt critical is exceeded). The kinetic equations in the latter case have been integrated numerically to facilitate the analysis.

ORNL-2341

Kasten P R, Fowler T B and Lietzke M P
FUEL COSTS IN SINGLE-REGION HOMOGENEOUS POWER REACTORS,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, December 3, 1957, 58 pp. (6 refs).

The fuel costs associated with electrical power produced from nuclear reactors will be a function of feed cost, inventory charge, fuel processing cost, and operating conditions. In order to better understand the relative importance of these costs under specified conditions, a parameter study was undertaken. The fuel cost as used here is defined as the cost of electrical power other than that associated with capital investment charges (reactor plant plus turbogenerator unit), fixed charges for fuel processing, and operation and maintenance charges. Included in the fuel cost is the cost of nuclear-fuel feed, inventory charge based on the initial fuel loading, and variable fuel-processing charges. Spherical single-region, homogeneous aqueous reactors are studied, moderated with either H_2O or D_2O and fueled with enriched UO_3 plus ThO_2, or UO_2SO_4 of varying enrichments. The effect of addition of Li_2SO_4 to the UO_2SO_4 was also considered. In the UO_3 + ThO_2 system, it was assumed that the initial fuel was U-235 and that a sufficient supply of U-233 was available as feed material. However, estimates were made of the effect upon fuel costs of using U-235 as feed material in nonbreeder reactors. The reactors were considered to operate at a temperature of 280°C and a pressure of 2000 psia. An 80% load factor and a net thermal-to-electrical efficiency of 25% was assumed. Thermal power level was considered to be 500 Mw for nearly all cases. The results obtained indicate that fuel costs based on nonsteady-state conditions are less sensitive to increases in fuel-cycle time than are fuel costs based on equilibrium conditions. However, for operating times greater than about 10 years, the optimum reactor conditions (reactor conditions refer to the specified reactor diameter, fuel-processing cycle time, and fertile material concentration) were about the same as those obtained on the basis of equilibrium conditions. The corresponding fuel costs were about the same for either 10- or 25-year operating periods. Based on present-day uranium values ($40/kg for natural uranium and $15/gm for uranium containing 90% U-235) and 4% inventory charges, reactors processed at the end of 10-year operation appear to have fuel costs as low as 1.4 mils/kw-hr. The cost is about the same as that for reactor systems having fuel-processing cycle times of 1 to 2 years, if, for such systems, the fixed charges for fuel processing and shipping are about 0.7 mil/kw-hr higher than for the batch-operated system. The optimum reactor conditions were a function of the inventory charge, effective fuel processing charges, reactor power level, fuel-feed value, reactor system, and the fission-product poisoning.

ORNL-2351

Thurber W C, Erwin J H and Beaver R J
THE APPLICATION OF A NOMINAL 48 WT % U-AL ALLOY TO PLATE-TYPE ALUMINUM RESEARCH REACTOR FUEL ELEMENTS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, March 11, 1958, 33 pp. (7 refs).

Under the Atoms-for-Peace Plan, the specification that uranium be limited to 20% enrichment in the U-235 isotope has necessitated development of a highly-concentrated uranium-aluminum alloy as the fuel material in the composite aluminum plates of research reactor fuel elements. Efforts have been directed to determining the suitability of a nominal 48 wt % U-Al alloy in relation to previously established procedures for manufacturing plate-type aluminum fuel elements.

Increasing the uranium concentration from 18 wt % to the 48 wt % resulted in increased segregation, higher strength, and loss of ductility, creating additional fabrication difficulties. Nonuniform deformation of the alloy during roll bonding into composite plates caused localized thinning of the cladding, which may limit the material to specific reactor applications. Substitution of Type 6061 aluminum for Type 1100 aluminum as frame and cladding of the fuel plates improves this condition.

A fuel element, containing the 48 wt % U-Al alloy, was irradiated in the active lattice of the MTR to an estimated burnup of 25% of the U-235 atoms with no observable damage.

ORNL-2379

Briggs R B (Project Director)
HOMOGENEOUS REACTOR PROJECT QUARTERLY PROGRESS REPORT FOR PERIOD ENDING JULY 31, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, October 10, 1957, 173 pp. (refs).

This document covers the progress of the homogeneous reactor project for the period from April 30, 1957 through July 31, 1957. Included is information on the operations and engineering changes to the Homogeneous Reactor Test during the quarter. These modifications include redesign of flanges, bellows, piping, etc. An iodine-removal bed was designed to minimize iodine poisoning of the fuel recombiner and to reduce xenon poisoning in the reactor.

During the quarter, the HRT mock-up terminated at 1580-hour run because of tube failure in the heat exchanger, but all systems ran during this time with no difficulties.

Analysis of the HRT makes it appear possible to run it in a blanket of thorium and achieve conversions as high as 0.6. Additional calculations concerning control, instrumentation, and the charcoal bed filter were completed during the quarter.

Preliminary flow sheets and design data were prepared for HRE-3, a 60-Mw thorium breeder reactor. A preliminary design for an oxygen pressurizing system was analyzed, and conceptual studies of the reactor-vessel configuration were started. These calculations included attempts to maximize breeding ratios.

In the engineering development section, several canned-motor blowers and pumps were investigated and work was performed on intergranular corrosion and stress corrosion. Additional work is covered in the area of reactor slurries as well as on valves and pressure transmitters.

The reactor materials section covers progress in solution corrosion, slurry corrosion, radiation corrosion and metallurgy pertaining to reactor components.

Development in the field of chemical engineering include uranyl-sulfate fuel processing, uranyl-sulphate blanket processing, and development of a thorium-oxide slurry. Work was begun at ORR on in-pile slurry loops for testing the various slurries.

Further work covered the fields of aqueous solutions at elevated temperatures, radiation chemistry, and analytical chemistry.

ORNL-2389-1

Johnson E B, et al.
STUDIES OF PLATE-TYPE CONTROL DEVICES IN A POOL-TYPE REACTOR,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 8 pp. (3 refs).

Both the proposed BSR-11 and the proposed TSR-11 pose problems of nuclear control because of the size or shape of the cores. Therefore the possibility of using plate-type control devices rather than rod-type devices is being considered. Experimental tests of the effectiveness of single and paired plates of absorber have been performed with the aluminum core of the BSR-1. The absorber plates used in these tests consisted of stainless-steel plates and boron-loaded aluminum plates which were inserted in various locations in a special fuel element. Other tests were performed with a two-dimensional mock-up of the TSR-11 control system. While extrapolation from the BSR-1 core to either of the proposed cores is not straightforward, experimental evidence indicates that plate-type control devices will provide an adequate control potential for each reactor.

ORNL-2389-5

Silver E G
COMPARISON OF POOL-TYPE REACTOR CRITICAL EXPERIMENTS WITH TWO-GROUP CALCULATIONS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (4 refs).

Critical masses calculated with the UNIVAC Eyewash and the Oracle 3G3R codes for three BSF reactor loadings were previously reported. These values have been revised slightly, as a result of a recalculation of the effect of partial elements on the flux. A few additional calculations have also been performed with a modified 3G3R code. In addition, the applicability of the 3G3R code used as a two-group code was verified by performing calculations for several solution-type reactors which required no geometric transformations.

ORNL-2389-7

Silver E G and Lewin J
DESIGN FOR A UO_2-STAINLESS-STEEL BULK SHIELDING REACTOR (BSR-11),
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 20 pp. (8 refs).

A design for an alternate core for the BSR, to be known as the BSR-11, has been completed. This reactor, which will be a 15-in. cube, will be a convection-cooled, plate-type research reactor fueled with highly enriched UO_2-stainless steel cermet clad with stainless steel. Nuclear calculations and heat transfer calculations, as well as the control-system dynamics, are presented.

ORNL-2389-8

Clifford C E and Holland L B
DESIGN FOR A SPHERICAL TOWER SHIELDING REACTOR (TSR-11),
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 18 pp. (11 refs).

A new reactor with a higher power and a geometry more amenable to calculations is needed at the TSF in order to extend the studies of the interactions of neutrons and gamma rays with air. In order to meet this need a new reactor, designated as the TSR-11, is being designed. It will be a 5-Mw, light-water-moderated and cooled heterogeneous reactor in a spherical geometry. The reactor will be controlled with curved

plates that will move radially in a spherical water reflector region interior to the core. Nuclear calculations have been carried out both on the UNIVAC and the Oracle in order to establish the reactor dimensions, and Monte Carlo techniques have been utilized to determine the gamma-ray heating in the lead. Development work on the fuel elements and the control mechanism has shown the mechanical design to be feasible. Control experiments are being performed with the BSR for correlation with calculations of the amount of nuclear control available.

ORNL-2389-10

Gwin R
DETERMINATION OF UNREFLECTED REACTOR PARAMETERS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (4 refs).

Data from a series of bare, aqueous, enriched U^{235} critical assemblies are fitted by diffusion theory by using both the "extrapolated end-point" method and the zero boundary return current, referred to as the "current" method. The just-critical conditions for all assemblies can be fitted well with one value of the buckling for each method. Measured reactor periods for off-critical dimensions are well fitted by the "current" method, but are in some question for the "extrapolated end-point" method. Ages and effective delayed neutron fractions are also calculated.

ORNL-2389-12

Dresner L, et al.
RESONANCE REACTOR PROGRAM,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 6 pp. (12 refs).

A program is planned in which an unreflected, graphite-moderated critical assembly with a resonance energy spectrum (1 to 100 kev) will be constructed. The assembly will be parallelepipedal in shape and will contain uranium enriched to 93% in U^{235}. Control will be effected by withdrawing fuel from the assembly and/or by separating the two halves of the assembly. The purposes of the program include the correlation of experimental and theoretical critical masses, the measurement of radiative cross sections, and the measurement of the capture-to-fission ratio.

ORNL-2389-22

Coveyou R R, Kinney W E and Sullivan J G, Jr.
'CORN PONE'-A MULTIGROUP, MULTIREGION REACTOR CODE,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp. (3 refs).

A multigroup, multiregion reactor code known as "Corn Pone" is nearing completion. Equations resulting from a consistent P_1 approximation to the Boltzmann equation are incorporated in the code. Hydrogen slowing down is treated exactly, while a variety of approximate slowing-down kernels for the heavier elements are available.

ORNL-2389-23

Wett J F and Coveyou R R
'MANFRED' - A 'FEW' - GROUP, MULTIREGION REACTOR CODE,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (1 ref).

A program designated as "Manfred" has been initiated to develop a "few" - group, multi-region reactor code for the Oracle. Manfred will allow the diffusion coefficient and the removal cross section to be spatially dependent. The code, by using the concept of albedos, collapses each region into a set of boundary conditions until the reactor is reduced to a core with a somewhat peculiar set of boundary conditions. Thus, in essence, the code reduces the problem to only one region, and, consequently, all the space points may be used in the core. After the flux in the core has been calculated, the fluxes in the other regions can be calculated by again making use of all the space points available.

ORNL-2389-25

LaVerne M E
EFFECTIVE BOUNDARY CONDITIONS IN THE THREE-GROUP, THREE-REGION REACTOR CODE,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (6 refs).

It has been found, in the Oracle 3G3R reactor code, that a manipulation of the boundary conditions allows the code to simulate the effects of regions outside the reactor and to do lattice calculations. Relations between shell β's and the shell transmission and reflection coefficients are shown. Shell β's for any transmission, but no reflection, are given.

ORNL-2389-27

Trubey D K, Moran H S and Weinberg A M
ESTIMATE OF THE NONLEAKAGE PROBABILITY FOR BARE AQUEOUS HOMOGENEOUS U^{235} REACTORS,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 7 pp. (13 refs).

The slowing-down distribution, to thermal energy, of neutrons from a U^{235} fission source in an infinite water medium up to 160 cm has been determined from experimental data. The Fourier transform of this distribution and the indium resonance distribution, which are the nonleakage probabilities for bare reactors, have also been determined.

ORNL-2389-36

Welch M J, et al.
STUDY OF AIR AND GROUND SCATTERING OF FAST NEUTRONS AT THE TOWER SHIELDING FACILITY,
Applied Nuclear Physics Progress Report for period ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 15 pp.

An experiment designed to study air and ground scattering of fast neutrons has been performed. A highly collimated beam of neutrons was obtained for the experiment by

placing either of two air-filled cylindrical aluminum pipes (8- and 15-in. ID) adjacent to the TSR in the reactor tank. Fast-neutron dose rate measurements were made with an unshielded detector at a distance of 64 ft from the reactor tank while both the direction of the beam and the height above the ground were varied. The measurements made as a function of altitude showed a maximum intensity at an altitude varying between 20 and 40 ft. A decrease in intensity as higher altitudes were approached resulted from a decrease in ground scattering that was larger than the small increase in air scattering.

ORNL-2431

MacPherson H G, (Program Director)
MOLTEN-SALT REACTOR PROGRAMS QUARTERLY PROGRESS REPORT FOR PERIOD ENDING OCTOBER 31, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, February 21, 1958, 44 pp. (11 refs).

This report covers the technical progress on power producing reactors fueled with circulating fused salts. The reactor design study covers the nuclear calculations, gamma heating of the core vessel, and the heat transfer system. The material study discusses metallurgy, radiation damage, and the chemistry involved. The system is evaluated for several molten salts.

ORNL-2432

Briggs R B, (Project Director)
HOMOGENEOUS REACTOR PROJECT QUARTERLY PROGRESS REPORT FOR PERIOD ENDING OCTOBER 31, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, January 21, 1958, 185 pp. (149 refs).

This report is a quarterly progress report on the homogeneous reactor project. The first section discusses the operation of the reactor in detail. This is followed by design and component development, reactor analysis, controls and instrumentation, the processing plant, and then the reactor design and analysis. There is a discussion on the development of fuel system components and reactor slurry systems. Detailed discussions are given on corrosion aspects and metallurgy. One section deals with chemical engineering development on slurries, fuels, and processing.

ORNL-2474

MacPherson H G, (Program Director)
MOLTEN-SALT REACTOR PROGRAM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING JANUARY 31, 1958,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 14, 1958, 115 pp. (30 refs).

This report discusses the design studies for a molten-salt reactor system. Lithium-beryllium and sodium-beryllium salts were studied. Component development and testing centered mainly about pump design with advanced reactor studies of natural convection, but it was found that natural convection required about 42% more fuel. In addition, metallurgical and chemical studies of radiation damage were conducted.

ORNL-2500 (Part 1)

THE ORNL GAS-COOLED REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April 1, 1958, 17 pp.

This report covers the pros and cons of an enriched uranium-gas cooled reactor versus a natural uranium system. A complete cost comparison is made of the two systems. It is recommended that a slightly enriched gas-cooled reactor be built in the near future.

ORNL-2500 (Part 2)

THE ORNL GAS-COOLED REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April 1, 1958, 23 pp.

In late September 1957, the Atomic Energy Commission undertook two separate studies at Kaiser Engineers and Oak Ridge National Laboratory to ascertain whether or not gas-cooled reactors should be given serious consideration as part of the reactor development program of the United States. The ORNL portion of this program was to consist of a design study of a graphite-moderated, enriched gas-cooled reactor, together with the research and development work on both natural and enriched gas-cooled reactors. The AEC requested that a detailed design report of an enriched gas-cooled reactor be submitted by ORNL on March 3, 1958. This is the required report (ORNL-2500, Pt. 2).

Because of the very tight time schedule, it was necessary from the beginning of the study to restrict the purview of the design work so as to insure completion of an adequate detailed design on a specific reactor plant for the purpose of comparing the performance of that plant with a natural-uranium, gas-cooled plant designed simultaneously by Kaiser Engineers.

The Oak Ridge National Laboratory offers the following conclusions which represent the opinion of the Laboratory on the basis of the work done through March 1, 1958 on the gas-cooled reactor program.

1. Adequate technology exists to build gas-cooled reactors in the United States either of the natural-uranium or the enriched-uranium variety, in the very near future.
2. An enriched gas-cooled reactor of the GCR-2 type will produce cheaper power than a natural-uranium plant. This follows from the large reduction in capital costs, achieved by enriching the fuel, combined with the fact that no serious penalty is paid in rising fuel costs as a result of fuel enrichment.
3. Gas-cooled reactors are at the present time technologically competitive with the best available pressurized-water reactors.
4. On the basis of recent paper studies, it appears that gas-cooled reactors are also competitive with pressurized-water reactors on an economic basis in the United States.
5. Both gas-cooled reactors and pressurized-water reactors have a substantial developmental potential to be realized in the future. There does not seem to be any fundamental reason for selecting one type for development to the exclusion of the other.

ORNL-2500 (Part 4)

THE ORNL GAS-COOLED REACTOR,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, April 1, 1958, 186 pp.

This report outlines the proposed plant design, with the site selection, plant layout in the building, and the fuel-handling facilities. There is a complete outline of the electrical facilities. There is a complete section on the cost analysis including the pressure vessel and fuel-element fabrication. There are three appendixes. One is on heat-transfer performance, one on reactor support and charging machinery, one on fuel-element cost data, and the final one on general design data.

ORNL-Q-1

HIGH VOLTAGE LABORATORY,
Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn., 11 pp.

This paper briefly discusses the High Voltage Laboratory at Oak Ridge National Laboratory. A history of the High Voltage Laboratory is included. A discussion is included on each of the four high voltage machines located there. The machines are a Cockcroft-Walton generator, two Van de Graaff generators, and a Cascade generator.

ORO-33

Beck Clifford K, et al.
PROGRAM ADMINISTRATION AND INSTALLATION DESIGN OF THE NUCLEAR REACTOR PROJECT AT NORTH CAROLINA STATE COLLEGE,
North Carolina State College, Contract No. AT-(40-1)-1032, July 5, 1950, 75 pp.

North Carolina State College of the University of North Carolina has proposed that a "water-boiler" nuclear reactor be built and operated on the college campus as an unclassified tool of instruction and research. A brief statement of the reactor project objectives and administrative procedure is made in this report. A tabulation has been included of hazards which could result from operation or misoperation of the proposed unit. Many safeguards have been included to prevent injury through such obvious and inherent hazards as exposure to radiation from the reactor and carelessness in handling radioactive materials in routing operations.

It is demonstrated that pressure rupture or explosion of the reactor by nuclear reaction is impossible. The "bubble effect" and a large negative temperature coefficient prevent any runaway whatever, and insure automatic upper limits to the level of operation, even if all normal and emergency safety devices fail.

This report is written in the form of a hazards summary.

POC/DATA-55

Whittle R H and Everson I
DIDO HIGH PRESSURE WATER LOOP DESIGN DATA FOR IN-PILE PRESSURE VESSEL,
Atomic Energy Research Establishment, Harwell, Berkshire, England, May (1957), 18 pp.

The two prime requirements of the pressure vessel for the high pressure water loop in Dido are:

1. That it should contain the high pressure safely.
2. That absorption of neutrons by the material of the vessel should not be excessive.

These two requirements are conflicting, and it is necessary to arrive at a suitable compromise.

This is a report of the method of analysis used to arrive at this compromise. Considering all factors including cost, there is little difference in relative desirability of Zircalloy over a chrome-moly-steel. For this reason a steel vessel is recommended for the original application with possible shift to Zircalloy should the flux attenuation of the steel vessel be found to be too great.

PPC-Q-1

Davis H W and Byron W J
THE DEVELOPMENT OF SOLID CORE QUICK-RELEASE SHIM ROD MAGNETS,
Prepared for presentation at the American Nuclear Society 1958 Winter Meeting, Detroit, Mich., Contract No. AT-(10-1)-205, December 8-10, 1958, 13 pp.

During 1957, a design and development program was initiated at the MTR to obtain replacement magnets for the MTR. Frequent failure and high maintenance costs were so prevalent that the program was justified.

The safe operation of the reactor depends to a great extent on the performance of the clutch magnet. It must hold the shim rod against high forces and yet release the rod in less than 15 msec if the reactor power overshoot is to be held below 300% N_F. Once the electrical and magnetic problems were solved, the mechanical design had to be attended to. The frame of the magnet had to support better than 600 lb. It also had to seal against the 70-psi tank water pressure.

During the year of operation on these magnets the MTR has not been shut down from magnet failure. The earliest two magnets are still on the reactor, unchanged, for a total of over 14 months of continuous operation. The maintenance costs have been approximately $3000 to date compared to the previous yearly expense of $9000. A definite advantage which is not obvious to one not familiar with the MTR is that only a pair of magnet amplifiers per magnet is necessary. Formerly a total of three per magnet was necessary.

PPC-278

Leyse C F and Wilson T R
CONCEPTUAL PROPOSAL FOR THE SPERT-III REACTOR FACILITY,
Reactor Projects Engineering Section, Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, October 28, 1955, 32 pp. (8 figs.)

This SPERT-III (Special Power Excursion Reactor Tests) design study describes a high pressure, high temperature reactor facility for conducting basic transient and reactor safety studies on heterogeneous water-cooled and moderated reactor cores. The facility consists of a two-loop primary system with heat removal provisions for operation at

power levels as high as 60 Mw for approximately 30 minutes. The major objective has been to design a facility with sufficient flexibility to permit several significantly different types of tests to be conducted over wide ranges of flow, temperature, and pressure.

PPC-326

Leyse C F, McPherson R S and Wilson T R
CONCEPTUAL PROPOSAL FOR THE SPERT-II REACTOR FACILITY,
Reactor Projects Engineering Section, Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, January 23, 1956, 30 pp. (8 figs.)

This SPERT-II (Special Power Excursion Reactor Tests) design study describes a reactor facility for conducting basic transient and reactor safety studies on heterogeneous water-cooled and moderated reactor cores at pressures up to 300 psi and water temperatures to about 400°F. The facility has provisions for conducting nonflow tests with either H_2O or D_2O moderator-reflector and flow tests with H_2O moderator-reflector.

PTR-51

Forbes S G
SPERT PROGRESS REPORT FOR THE PERIOD JULY THROUGH DECEMBER 1955,
Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT-(10-1)-205, February 1, 1956, 14 pp. (4 refs).

This report is a summary of the tests conducted by the SPERT Staff on the SPERT-I reactor from its initial operation in July 1955 to the end of the calendar year.

A brief description is included of a series of static measurements undertaken to provide essential data for the interpretation of transient experiments. A section is included which discusses transient tests.

To obtain detailed information on the reactor transient behavior, physical measurements at several points within the core are essential. Therefore, a section has been included discussing detector development.

R-316

Safonor G
EXTERNALLY MODERATED REACTORS,
The Rand Corporation, Santa Monica, California, July (1957), 39 pp. (7 refs).

The term "externally moderated reactors" appropriately describes a group of systems that include a rather wide variety of design possibilities. Such systems are characterized by two basic regions: fissile material is contained in a central region, the "interior", which is surrounded by an "exterior" consisting of a good moderating medium. If the interior materials are distributed with such a low density that the dimensions of the central region are small relative to a slowing-down length there, the amount of internal moderation will be small. Also, if the interior materials exist at normal densities, but have high atomic weights or high absorption cross sections, the internal moderation may be insignificant. In such reactors, the degree of interior moderation may be small enough to justify a first analysis with the assumption of complete external moderation.

A reactor-statics theory is presented for a group of thermal systems having spherical symmetry.

REIC-7 AD-157174

Kircher J F
SURVEY OF IRRADIATION FACILITIES,
Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio, Contract No. AF33(616)-5171, May 31, 1958, 98 pp.

This report presents a survey of irradiation facilities generally available to the Air Force and its contractors. Reactor facilities, gamma facilities, and high-energy machine sources have been included in this survey. The listed information on reactor facilities includes fast neutron flux, thermal neutron flux, gamma dose rate, power and type, status, moderator, coolant, shield, operating schedule, and irradiation space. The information listed on gamma facilities includes source, dose rate, sample environment, sample-container size, temperature, policy, and inquiries regarding services. Typical information listed concerning high-energy machine sources is type and strength of source, energy range, machine output, most acceptable sample size, source configuration and geometry, total capacity in pounds, policy and inquiries regarding services.

REIC-7 (Add. 1)

Kircher J F and McFarling J L
SURVEY OF IRRADIATION FACILITIES (FIRST ADDENDUM),
REIC, Battelle Memorial Institute, Columbus 1, Ohio, February 15, 1959. 4 pp.

This report is an addendum to REIC Report No. 7, "Survey of Irradiation Facilities," and contains brief descriptions of reactor facilities completed in the past years, those under construction, and those in the planning stage. Additional gamma facilities are listed also.

REPF-103

Gage Avery M
DESIGN OF THE SHIELD FOR THE OMEGA WEST REACTOR,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico, February (1957), 104 pp., (12 refs).

This paper on the design of the shield of the Omega West Reactor (OWR) contains a brief description of the reactor, the general design considerations for the shield, methods of calculating the attenuation of gamma rays and neutrons, the determination of the required density and thickness of the concrete, and the design of concrete mixes to meet the requirements. The calculations and design for the special shielding for the thermal column, the top, and for ducts in the concrete is given. Also a brief description is given of the facilities for measuring temperatures and gamma and neutron fluxes in the shield.

REPF-107

Malaker Stephen (Dr.)
NUCLEAR REACTORS AND INTEGRATED CONTROL SYSTEMS,
Daystrom, Inc., Archbald, Pennsylvania, 12 pp. (5 refs).

The projected growth of nuclear power plant stations indicates that they will be a cogent economic factor within the next decade. Up to the present time, nuclear power has had

little chance for empirical evaluation so that a history of past operational performance is lacking. In the current transition period from research and production-type reactors to power reactors, much of the control philosophy has been based on adaptations of proven techniques to bridge the existing gap. Considerable experience has been accumulated on conventionally fueled power plants, and the present nuclear power plant control systems are marriages of convenience between standard boiler controls and quasi-standard reactor controls.

Since the presently envisioned nuclear control station power plant tends to use existing conventional steam turbines and accessory equipment, the greatest innovations and extrapolations are on the reactor side of the heat exchanger. Most previous experience has been with reactors which are controlled externally by means of electromechanical equipment and those which are periodically refueled during shutdown. The contemplated power reactors, however, have inherent stability and self-regulation with provision for fuel processing without being taken off the line.

RSI-0557-1

Coltman R R, Blewitt T H and Noggle T S
TECHNIQUES AND EQUIPMENT UTILIZED IN LOW-TEMPERATURE REACTOR IRRADIATIONS,
Review of Scientific Instruments, Vol. 28, No. 5, pp. 375-380, May (1957), (5 refs).

A cryostat used in hole No. 12 of the graphite reactor at Oak Ridge National Laboratory is described in detail. The cryostat which is made almost entirely of aluminum is supplied with cold helium gas from an Arthur D. Little helium refrigerator. Bombardments have been made in the cryostat at temperatures as low as 15°K for periods as long as two weeks. A discussion of the equilibrium temperature attained by a specimen in the cryostat is given taking into account the reactor gamma-ray heating effects. A method for measuring stored energy and specific heats of materials bombarded in the cryostat utilizing gamma-ray heating is described. A method for pulse annealing specimens at low temperatures employing the discharge of the energy stored in a bank of condensers is also described. Relatively sharp and quite reproducible thermal pulses can be obtained with this method (which is also suitable for use in the laboratory). The hazard of cryogenic devices in high radiation fields is discussed. It is believed that when air is allowed to condense on a cold surface in the presence of intense ionizing radiations, a hazardous condition results.

SCR-52

Morse T B
FACTORS IN THE DESIGN OF AN ENVIRONMENTAL CHAMBER INSIDE A REACTOR IRRADIATION CELL,
Sandia Corporation, Albuquerque, New Mexico, Contract No. AT-(29-1)-789, October (1958), 11 pp.

This report discusses the design of an environmental chamber inside of a reactor irradiation cell. An outline is given of the operating conditions desired in the test chamber. The topics discussed are materials, duct systems, test chamber, air filter, dampers, air heater, air cooler, fan, vacuum pump, vibration equipment, equipment and control rooms, and instrument and control leads to the test chamber.

SCTM 9-58(16)

Coppage F N
SERF MOBILE BIOLOGICAL SHIELD-CONTROL SYSTEM,
Sandia Corporation, Albuquerque, N. Mex., Contract No. AT-(29-1)-789, January 27, 1958, 26 pp.

This report contains preliminary information on a proposed control and power system for the mobile biological shields of the Sandia Engineering Reactor Facility (SERF). The shields, four in number, will be divided into six doors, which will range in weight from 73 to 275 tons. This report will discuss the desired features of such a system, a proposed control system, and possible difficulties to be encountered with the system. The SERF proposal is not yet completely firm, and information on some phases of the program is limited. As a result, changes to the control and power system proposed in this report may be required. Any such changes will be described in subsequent reports.

SCTM 52-59(51)

Carlson Roland H
THE CONSTRUCTION OF GEOTHERMAL STEAM POWER PLANTS UTILIZING NUCLEAR EXPLOSIVES,
Sandia Corporation, Albuquerque, N. Mex., June 5, 1959, 31 pp. (13 refs).

An investigation is made of the feasibility of using nuclear explosives in the construction of geothermal steam power plants. Geothermal steam plants now in operation, proposed geothermal projects, areas of possible exploitation, and possible methods whereby nuclear explosives may be employed are discussed. Economic advantages of nuclear applications are indicated. It is concluded that realistic applications of nuclear explosives to geothermal power-plant construction do exist.

SCTM 276-59(12)

Wilcox B
AN APPROXIMATE STUDY OF THE PERFORMANCE OF A REACTOR-HEAT EXCHANGE SYSTEM,
Sandia Corporation, Albuquerque, N. Mex., August 10, 1959, 23 pp. (2 refs).

The coolant temperatures at the inlet and outlet of a reactor and connected heat exchange units are determined for variations in coolant flow parameters. In addition, the power regulation of the reactor is determined for these variations under several conditions of fuel loading. Equilibrium conditions are assumed.

SCTM 443-58(51)

Kantz A D
SANDIA VAN DE GRAAFF ACCELERATOR,
Sandia Corporation, Albuquerque, N. Mex., Contract No. AT-(29-1)-789, December (1958), 52 pp. (17 refs).

An increasing interest in the effects of high-energy radiations on materials pointed out the necessity for increased research activity at Sandia Corporation in this field. A facility to control the mass, charge, energy, flux rate, and total dose of incident radiation to simulate radiations found in nuclear detonations is desirable. A survey of

characteristics and the utilization of particle accelerators was made to determine the contribution of such facilities to the Sandia research programs.

The operating principles of various accelerator types are enumerated. The large Bev machines are included to complete the summary of the present state of accelerator art, although these are not directly related to Sandia programs.

The accelerator found most versatile for research use was a Van de Graaff generator. The facility established at Sandia is described in some detail. The general areas of radiation effects studies are briefly discussed to present a general background of the research program in radiation effects.

TID-2504 (Del.)

Reynolds, M. B, et al.
REACTORS-RESEARCH AND POWER,
Technical Information Service, Oak Ridge, Tenn., December (1953), 361 pp.

(A series of reports.)

TID-3068

Lanier, Sidney F
THE SHIPPINGPORT PRESSURIZED WATER REACTOR,
USAEC Technical Information Service, Oak Ridge, Tenn., February (1958), 33 pp. (193 refs).

A total of 193 annotated references to unclassified reports on the design, development, and construction of the Shippingport Pressurized Water Reactor is presented. Author, subject, and report number indexes are included.

TID-3501

Scott Thomas W
UNCLASSIFIED U.S. ATOMIC ENERGY COMMISSION REPORTS ON CIVILIAN POWER REACTORS AND TEST REACTORS,
A literature search. USAEC Technical Information Service Extension, Oak Ridge, Tenn., November (1956), 4 pp.

This report lists a group of references found as a result of a literature search and which pertain to civilian power reactors and test reactors.

TID-3506

Lanier Sidney F
UNCLASSIFIED U.S. ATOMIC ENERGY COMMISSION REPORTS ON CONTROLLED THERMONUCLEAR PROCESSES,
A literature search. USAEC Technical Information Service Extension, Oak Ridge, Tenn., January (1957). 7 pp.

This report is a bibliography of 40 references to reports dealing largely with the mathematical analysis of highly ionized plasma in electric and magnetic fields and proposed containment devices of interest to the controlled release of thermonuclear energy.

TID-3530

Lanier Sidney F
PRESSURIZED WATER REACTORS,
USAEC Technical Information Service, Washington 25, D.C., 31 pp.

This literature search was prepared to fill a specific request. However, because of wide interest in the subject, it has been printed to fill other needs. The search is limited to references on the Shippingport Pressurized Water Reactor, the Army Package Power Reactor, the Indian Point Reactor, the NS Savannah (nuclear merchant ship) Reactor, and general reports on pressurized water reactors. All references listed are unclassified.

TID-5031

Lansing N F (Compiled by)
THE ROLE OF ENGINEERING IN NUCLEAR ENERGY DEVELOPMENT,
Proceedings of the Third Annual Oak Ridge Summer Symposium, Sponsored by American Society for Engineering Education, August 27 to September 7, 1951, Oak Ridge National Laboratory, Oak Ridge, Tenn., December (1957), 509 pp. (102 refs).

The report of this symposium contains 23 papers on the general subject of the role of engineering in nuclear development. General topics such as the objectives of the AEC, aspects of atomic power, the AEC reactor program, and engineering in nuclear development were presented.

Three papers on scientific background were presented: "Underlying Concepts of Nuclear Physics," "A Simplified Approach to Reactor Calculation," and "Standards of Radiological Protection and Control."

Engineering aspects were the main part of this symposium and covered such areas as chemical problems, reactor materials, heat transfer problems, instrumentation and control, shielding, wastes, hazards, and a survey of reactor types.

The symposium closed with a panel discussion on the scope of nuclear engineering and the impact of and need for training in nuclear engineering.

TID-5202

Mills M M
MINUTES OF ATOMIC ENERGY COMMISSION SYMPOSIUM ON REACTOR HAZARDS,
USAEC Technical Information Service Extension, Oak Ridge, Tenn., April 15, 1950, 19 pp.

This report concerns itself only with reactor phenomena and is not concerned with the effects internal to the reactor shield.

The mechanical effects may be qualitatively classified as dynamical, and quasi-static. Equations are developed which indicate the standard result that violence is proportional to the cube of excess reactivity. The violence of a fast accident goes up about as the square rather than the cube. A comparison with TNT is made and the conclusion is reached that the mechanical effects of a reactor accident can actually be contained within the reactor shield.

TID-5272

Bolwell H
FINAL TEST REPORT - ORNL CONTROL ROD DRIVE MECHANISM,
American Machine and Foundry Company, General Engineering Laboratory, 11 Bruce Place, Greenwich, Conn., August (1954), 25 pp.

Upon completion of the feasibility study (ORNL CFN 53-10-106) of a packaged pressurized water reactor power plant, it was felt that several of the components of the nuclear power plant should undergo various degrees of testing to further prove their feasibility.

The American Machine and Foundry Company was contracted by the Oak Ridge National Laboratory to build and test a control rod drive mechanism, control rod latch, control rod guide bearings, and shock absorber.

The components of the drive mechanism were to be the same as those specified in ORNL CFN 53-10-106. They were to be mounted in breadboard fashion, since it was not deemed necessary to make any attempt toward final packaging of the unit.

A dummy control rod was used during the test. The rod was made of stainless steel and to the same dimensions as the actual rod. It contained the same number of dummy fuel plates, and correct plate spacing was maintained.

This was not a program to fully develop and prove out the design. It was rather, a program to determine whether a drive mechanism containing such components as a rotary seal, rack, and pinion and rod latch was feasible for the package power plant.

TID-5280

FOURTH ANNUAL SYMPOSIUM ON HOT LABORATORIES AND EQUIPMENT, HELD IN WASHINGTON, D.C., SEPTEMBER 29 AND 30, 1955,
Argonne National Laboratories, Lemont, Illinois, September (1955), 383 pp. (16 refs).

(Report on topics discussed.)

TID-5280 (Suppl. 1)-1

Bevilacqua Frank
ELECTRICAL DISCHARGE MACHINES FOR HOT LABORATORIES,
Argonne National Laboratory, Lemont, Illinois. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, Washington, D.C., September 29 and 30, 1955, 12 pp. (4 refs).

An electric discharge method of removing metal is being studied at Argonne National Laboratory with a view to using it to perform machining operations on radioactive fuel elements. A simple test machine was constructed which allows good contamination control and ease of operation in the hot laboratory facility.

TID-5280 (Suppl. 1)-3

Angel C W
REMOTE REACTOR MANIPULATIONS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, Washington, D.C., September 29 and 30, 1955, 13 pp.

Means for remote manipulation and control of reactor are described.

TID-5280 (Suppl. 1)-4

Eichenberg J D and Bleiberg M L
DESIGN OF A STORAGE SAFE AND A CUT-OFF WHEEL FOR HOT LABORATORY USE,
Westinghouse Atomic Power Division, Pittsburgh, Pa. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, Washington, D.C., September 29-30, 1955, 10 pp.

In order to perform necessary testing of irradiated materials in hot laboratories, it is required that standard equipment be modified for remote control. Two such units are described in this paper, namely, a storage safe and a cut-off wheel.

A storage safe was designed to provide temporary and convenient storage for irradiated specimens so as to allow access to the cell for equipment repair, etc. The over-all safe dimensions are 27" wide x 27" deep x 26-7/8" high with a storage box 6-1/8" wide x 9-3/4" deep x 12-5/8" high. There is 3-1/2" of lead shielding on the top and two sides of the safe, 2-3/8" of lead on the back, and 1" of lead on the bottom. Two split lead doors, 3-1/2" thick, are easily opened and closed with a master slave manipulator by means of a cantilever hinge assembly.

A remotely controlled cut-off wheel was designed for cutting radioactive samples. An air vise is used for holding the specimens and a hand-operated shaft is employed to turn the vise and sample into an abrasive wheel under water. A spray system and remotely removable sump can are provided for decontamination. The cut-off wheel spindle and vise assembly are easily removed in event of a breakdown.

TID-5280

FOURTH ANNUAL SYMPOSIUM ON HOT LABORATORIES AND EQUIPMENT, HELD IN WASHINGTON, D.C., SEPTEMBER 29 AND 30, 1955,
Argonne National Laboratories, Lemont, Ill., September (1955), 383 pp. (16 refs).

This report is the 4th Annual Symposium on Hot Laboratories and Equipment. The topics discussed are as shown below:

Master Slave Manipulators
BNL Spent Fuel Chopper
Corrosion Testing Facility
Stabilizer Consumption in ZnBr Windows
Shielding Windows
Hot Cells
Automatic Gamma Irradiation Chamber
Mobile Shielder Equipment
Remote Tools and Facilities
Radioactive Handling

TID-5280 (Suppl. 1)-6

Blomgren R A and Bohlin N J G
PROPOSED METHODS FOR REMOTE TRANSFER OF ALPHA AND GAMMA ACTIVE MATERIALS INTO AND OUT OF HIGH LEVEL CAVES,
Remote Control Engineering Division, Argonne National Laboratory, Lemont, Ill. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, Washington, D.C., September 29-30, 1955, 12 pp.

Two methods for transferring alpha and gamma contaminated equipment have been designed as part of the handling system for the Radiochemistry Cave proposed at Argonne National Laboratory.

One method consists of pushing a container or filter into its loading or working position in a tunnel as an initial step and then pushing it on through with a new container or filter. Special gaskets on the filter or container keep it sealed during transfer including its final location in a shipping container.

A second method for transferring materials through an aperture in the vertical wall of a cave is to seal the clean side of a container cover to an inner cave door before the door is opened. When the inner cave door is opened, the container seals the aperture. The parting line between the container seal and the cave seal is the minimum area to become contaminated.

TID-5302 (Rev)

PWR FUEL ELEMENT SPECIFICATIONS,
Atomic Power Division, Westinghouse Electric Corporation, Pittsburgh, Pa., May (1957), 71 pp.

This report has listed in detail the PWR fuel element specifications.

TID-7001

Buck J H and Leyse C F
MATERIALS TESTING REACTOR PROJECT HANDBOOK,
Argonne National Laboratory, Lemont, Ill., and Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May 7, 1951, 582 pp.

This handbook for the Materials Testing Reactor has been put together at the request of the MTR Steering Committee. It was the feeling of the Committee that the principal purposes for the report should be: (1) to give a semidetailed description of the reactor, and (2) to explain, insofar as possible, the reasons for the design. In order to carry out these purposes the Handbook has been divided into a series of chapters and appendixes as follows:

a. Chapter 1 presents a general description of the reactor and its auxiliaries and an account of the administrative history of the project.

b. Chapter 2 gives a description of the reactor as it is now being built. While this chapter inevitably gives some of the reasons for the present design, the main background and experiments leading to the MTR are described in Appendixes 1 thru 6.

c. Chapter 3 describes the experimental facilities provided in the reactor. Some facilities that have been proposed and will probably be built later are described in Appendixes 9 and 10.

d. The various aspects of the physics of the reactor are described in Chapter 4, which leads up to the control of the reactor discussed in Chapter 5. Some general nuclear data are given in Appendixes 7 and 8.

e. Chapters 6 thru 10 are devoted to a description of the necessary auxiliary units to the reactor proper and the reasons for their design.

Extensive bibliographies and lists of reference drawings are given at the end of each chapter so that the reader, if he wishes, may find further details in original reports and memoranda.

TID-7013

U.S. RESEARCH REACTORS,
Prepared by Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, for Technical Information Service, USAEC, Oak Ridge, Tenn., August (1957), 73 pp.

The reactors described in this booklet are, with a few exceptions, built to produce a copious supply of neutrons - and gamma rays - for research. A research reactor can be defined as one built primarily for the purpose of gaining information rather than for producing useful power or transmuted substances.

This booklet provides a compact summary of technical information on the major types of research reactors developed in the US. Cost information is given for most of the reactors described. Nearly all research reactors built thus far in this country fall into one of three general classes: light water moderated, heavy water moderated, and graphite moderated reactors. Within each class, size and power vary over a considerable range.

A list of research reactors built, building, or planned in the US, including those for foreign locations, is included at the end of this booklet.

TID-7014

Fosdick Ellery R
AEC HOT CELLS AND RELATED FACILITIES,
AEC, Division of Construction and Supply, Washington, D.C., May (1958), 103 pp.

The primary purpose of this report is to present an accumulation of basic information on the hot cells constructed to date by the USAEC.

The need, by both the Government and industry for information on hot cells constructed by the AEC, has been increasing as the atomic energy program in the US has expanded. Hot cells are basic tools that are used in almost all phases of the atomic energy program for research, development, and operation in connection with irradiated materials.

To obtain the basic information needed for this report, the AEC Division of Construction and Supply prepared a questionnaire, with the advice and assistance of the Division of Reactor Development, which was sent by the Division of Reactor Development in December 1956 to each AEC operations office where hot cells are located. This report is a compilation of the data supplied in reply to these questionnaires; in addition, it includes information on unit construction costs and related matters.

Additional information is needed regarding the preferred type of biological shielding to be used, standardization of biological shielding, and shielding-window thickness and

related matters. Further study of these matters should be undertaken, directed toward the establishment of design criteria for hot cells and the development of a standard specifications.

To facilitate comparison of the various cells, unless otherwise indicated, they are rated in terms of 1-Mev gamma sources.

TID-7529 (Pt.1)

REACTOR HEAT TRANSFER CONFERENCE OF 1956,
Collected Papers and Reports of a Conference Held at New York, November 1-2, 1956,
Nuclear Development Corporation of America, White Plains, New York, (1956), 315 pp.

This document consists of the papers in the physics and mathematics portion of the "Reactor Heat Transfer Conference of 1952," held on November 1st and 2nd. A second book of the same title covers an equal number of papers on the same subject (physics and mathematics of reactor heat transfer) and a list of attendees. The following is a list of papers and their authors as contained in this document:

A General Method of Determining the Total Time Integral of Transients in Linear Systems - K. C. Jordan

Basic Equations Describing Energy Flow and Pressure Drop Relationships for Transient Coolant Flow Conditions in a Nonhomogeneous Plate-Type Reactor - Edward V. Somers

Rapid Flow Transients in Closed Loops - A. J. Arker and D. G. Lewis

Fast Transient Heat Transfer in a Clad Element - Stagnant Water System - Michael Markels, Jr., and Warren A. Stark

Transient Heat Conduction in Solid Cylindrical Nuclear Fuel Elements - Frank E. Tippets

Response of Nuclear Reactor Coolant to Power Transients - John A. Clark, Vedat S. Arpaci, and Kenneth M. Tredwell

Transient Thermal Analysis by Means of Analog Computers - I. W. Underwood, J. H. Pigott, and R. L. Mathews

An Analysis of Fuel-Plate Temperature Rise During a Burnout Transient - B. W. LeTourneau and R. E. Grimble

In-Pile Molten Metal-Water Reactor Experiments - O. J. Elgert and A. W. Brown

Pressure Drop in Rectangular Channels at 2000 psia-S. J. Green, H. S. Jacket, J. D. Roarty, N. C. Sher, G. Sonnenmann, A. Weiss, and J. E. Zerbe.

Flow Redistribution Due to Boiling in a Matrix - J. P. Fraser

Investigation of Burnout Heat Flux - R. A. DeBortoli, S. J. Green, H. S. Jacket, J. D. Roarty, A. Weiss, and J. E. Zerbe

Nucleate and Film Boiling Due to Repetitive Pulse Heating of Small Wires Immersed in Water - E. A. McLean, V. E. Scherrer, and C. E. Faneuff

Tubular versus Plate Fuel Elements: Heat Transfer and Flow Analysis - R. A. Cushman and W. W. Cunningham

Heat Transfer Within the Cores of Circulating-Fuel Reactors - H. F. Poppendiek

Heat Transfer and Hydraulic Characteristics of the SRE Fuel Element - T. T. Shimazaki and W. J. Freede

Heat Transfer Rates to Cross-Flowing Mercury in a Staggered Tube Bank - II - C. L. Rickard, O. E. Dwyer, and D. Dropkin

TID-7532 (Pt. 1)-2

Henry A F
REVIEW OF METHODS USED IN CONTROL ROD ANALYSIS FOR REACTOR DESIGN AT BETTIS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 7 pp. (1 ref).

The methods, both exact and approximate, currently being used at Bettis for computation of shutdown and power distribution in a reactor controlled by rods are reviewed.

TID-7532 (Pt. 1)-3

Auerbach T
FORMULAS FOR CONTROL ROD WORTH IN THERMAL REACTORS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 5 pp. (4 refs).

The reactivity controlled by an arbitrary arrangement of rods in a cylindrical reactor is derived on the basis of a generalized Nordheim-Scalettar method. It is illustrated by means of a two-ring array of rods, and its limitations and possible extensions are discussed briefly.

TID-7532 (Pt. 1)-4

Stevens H E
HALF-GROUP THEORIES FOR CONTROL RODS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 12 pp.

The Area Absorption Theory for black control rods in a thermal reactor has been extended to transparent control rods with epithermal as well as thermal absorption. Combined with the half-group diffusion methods, a reliable, flexible, economical tool is available for scoping evaluations. Comparison of theoretical results with experimental data has given good agreement. Construction graphs are included and simple control rod cases are demonstrated.

TID-7532 (Pt. 1)-5

Stewart J C and Francis N C
VARIATIONAL CALCULATION OF CONTROL ROD AND WATER GAP INTERACTIONS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 5 pp.

A variational method, suggested by Hurwitz, has been applied to the calculation of self-shielding factors from the one-velocity Boltzmann equation. Isotropic scattering

and slab geometry have been assumed, though the method is of more general applicability. Analytical results are described for the isolated slab, and the (numerical) extension to a periodic array is discussed.

TID-7532 (Pt. 1)-6

Smith J H
THE EFFECT OF EPITHERMAL ABSORPTIONS ON CONTROL ROD ABSORPTION AREA,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 1 p.

A technique is described for the modification of control rod absorption area to include the absorption of epithermal neutrons by the rod.

TID-7532 (Pt. 1)-8

Betinis E J
FLUX DISTRIBUTION FOR A FINITE CYLINDRICAL BARE HOMOGENEOUS THERMAL REACTOR WITH A PARTIALLY INSERTED CONTROL ROD,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 6 pp. (2 refs).

One-group diffusion theory is employed to determine the flux for a large but finite cylindrical bare homogeneous reactor with a control rod inserted partially along the axis of the reactor. A critical equation is derived for the buckling.

TID-7532 (Pt. 1)-9

Stuart G W
DEPENDENCE OF CONTROL ROD WORTH ON REACTOR TEMPERATURE AND FUEL EXPOSURE,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 6 pp.

A "recipe" is presented for calculating the change in control rod worth as a function of neutron temperature and reactor exposure. Only thermally black rods inserted in heterogenious reactors are considered. Sample calculations are presented which reveal that the aforementioned variations can be of significant magnitude.

TID-7532 (Pt. 1)-10

Lightle R E
MULTIPLE CONTROL ROD CALCULATIONS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 12 pp.

This paper discusses an analytic method of calculating two concentric rings of control rods in a homogeneous cylindrical reflected reactor. Arguments are given to support the choice of boundary conditions chosen. A modified two-group energy model is presented. Some of the computational problems which arise from the formulation are discussed.

TID-7532 (Pt.1)-11

Lanning D D
HETEROGENEOUS REACTOR CRITICAL CONDITION USING SMALL SOURCE THEORY,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 12 pp. (8 refs).

Calculations using Small Source Theory have been made for the critical conditions of reactors with an annular-type fuel loading. The first reactor considered is loaded with fuel tubes but has no control rods. The calculated critical mass of U^{235} is 10.6 kg which agrees with the approach to critical experiment within the experimental error. The next case considered is the addition of control rods to a similar type reactor, which is approximately like the PCTR now operating at Hanford. The calculated effect on the critical mass of adding these special type control elements is 1.28 kg of U^{235} which is to be compared with a measured effect of 1.34 kg. The calculated control strength of these rods is 1.14 kg and the measured strength is 0.96 kg.

TID-7532 (Pt.1)-12

Hartley W H and Bayard R T
CONTROL ROD WORTH STUDIES ON SEED AND BLANKET REACTORS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 6 pp.

A technique is described for determing control rod shutdown reactivity for tall reactors (small relative axial leakage) which may also be applicable to other reactor geometries. This method assumes that the rod bank region is an exponential assembly with the critical portion of the reactor as the driving source for the exponential. Comparison is made with the results obtained from the rod drop technique.

TID-7532 (Pt.1)-13

Brown J H
LIMITATIONS OF SCRAM TRANSIENT CALIBRATIONS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 6 pp.

Among the ways of measuring the strength of a control rod or system of rods is the so called 'scram transient method'. In this procedure the reactor is brought to a particular power level and the control to be measured is inserted. A record of the flux as a function of time is obtained and analysis is performed to determine the control strength. This paper will point out some of the difficulties associated with this method.

TID-7532 (Pt.1)-14

Fairbanks F B and Gallagher J G
APPR-1 CONTROL ROD EXPERIMENTS AND CALCULATIONS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 23 pp. (12 refs).

The methods used to treat partially and fully inserted APPR-1 control rods are described. The fully inserted control rods are treated by methods developed by Dr. R. L. Murray. The worth of the centerline and 5-rod bank show good agreement

with experiment. Partially inserted control rods are treated by the window shade model. Good agreement was obtained for partial insertion in clean reactors and poor agreement with poisoned reactors. Calculated flux distribution and relative shim bank worth showed good agreement with experimental results.

TID-7532 (Pt.1)-15

Perry A M
APPR CONTROL RODS - THEORY AND EXPERIMENT,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 13 pp. (9 refs).

A method of control rod analysis has been developed which takes into account the nature of the material in the interior of the control rod and its effect upon the fast neutron flux. Calculated reactivity values of APPR control rods in various combinations are in excellent agreement with experimental results obtained in a critical mockup of the reactor.

TID-7532 (Pt.1)-16

Carmichael B M and Battat M E
CONTROL ROD WORTHS VS TEMPERATURE IN LAPRE I,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 13 pp. (7 refs).

An analysis is made of the factors affecting the reactivity control of LAPRE I (Los Alamos Power Reactor Experiment I) based upon experimental data obtained in a recent hot critical run. At cold critical a total control rod worth of 6.27% and an effective delayed neutron fraction of 0.0091 are obtained from reactor volume and period measurements. The interaction between the internal reservoir and core during the thermal expansion of the fuel solution is illustrated by plots of the solution temperatures versus control rod positions. The reactivity perturbations encountered in reaching a power level of 180 kw at a core temperature of 388^{o}C are discussed.

TID-7532 (Pt.1)-17

Bach D R and Kitchen S W
EFFECTS OF ROD SHAPE ON CONTROL ROD WORTH,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 12 pp. (2 refs).

Measurements have been made of the effectiveness of axial slab and cross-control rods in a highly enriched, polyethylene moderated cylindrical critical assembly. Materials studied include cadmium, hafnium, and boron dispersions in aluminum. These experiments were initiated in order to determine the applicability of the absorption area concept developed by Hurwitz and Roe to practical reactor problems.

The data indicate that for the range of thicknesses and materials studied, geometry and transmission effects on control rod worth are separable. In addition, the ratio of the worth of a slab of width 2a to that of a cross of width 2a having the same transmission is independent of the transmission.

If the absorption area concept is to have meaning, two absorbers occupying the same position in a reactor and having the same absorption area must necessarily have the same control effectiveness if the migration area is greater than the absorption area. This type of comparison of the Hurwitz and Roe theory with the data shows good agreement. A direct comparison of the calculated absorption area with measured rod effectiveness shows that for the range of $\Delta k/k$ measured, a thermal diffusion length of 0.6 inches, and for $1'' \leq \alpha \leq 4''$, $\Delta k/k$ is proportional to the absorption area.

TID-7532 (Pt. 1)-18

Price G A
LATTICE EXPERIMENTS WITH THIN BLACK CONTROL RODS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 6 pp.

Control rod worth experiments were performed in critical assemblies of 1.3% U^{235} rods, 0.387" diameter, ordinary water moderated and reflected. Control rod radii varied from .231 cm to .672 cm. The observed control rod worths and effective control rod radii are shown to be considerably less than would be expected from diffusion theory calculations.

TID-7532 (Pt. 1)-19

Iskenderian Haig P
THEORY AND EXPERIMENTS ON RODS CONTAINING RARE EARTH METALS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 6 pp.

Formulae and curves are given for the determination of the effectiveness of control rod materials in thermal reactors.

The constants (two) appearing in the formula for total neutron absorption are determined empirically. The validity of the formula is then checked for measurements on a number of slabs of different materials. An agreement of about 6% exists between calculated and measured values.

TID-7532 (Pt. 1)-20

Wick R S
AN EMPIRICAL DETERMINATION OF THE FAST ABSORPTION CONSTANTS OF CONTROL RODS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 12 pp.

This paper outlines a method for estimating the fast absorption cross section of 70 w/o silver and 30 w/o cadmium cruciform shaped control rods used in a series of critical assemblies in slab geometry. The method consists of a synthesis of a slab-type reactor with the control rods at a uniform height along the center of the slab by a series of one-dimensional calculations using assumed values of the control rod fast absorption cross section. The calculated values of the criticality and the flux shape in the rodded region for a measured control rod bank height are compared to the measured flux shapes and the assumed value of rod fast absorption which gives the best correspondence is taken as the empirical value. The best value of the macroscopic fast absorption obtained from analysing three different critical reactors was 0.21 cm^{-1} for the cadmium-silver rods.

TID-7532 (Pt.1)-21

Loewenstein W B
THE CONTROL OF FAST REACTORS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 4 pp. (2 refs).

The parameters pertaining to the control of a fast neutron chain reacting system are discussed. Special emphasis is placed on topics where such control techniques differ from the problems associated with the design of thermal reactors.

Control considerations inherent in the design of EBR-II and experimental ZPR-III results form the basis for much of the discussion.

TID-7532 (Pt.1)-22

Radkowsky A
THE GENERAL APPLICATION OF BURNABLE POISONS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 9 pp.

This paper outlines a generalized treatment of burnable poisons, as a substitute for mechanical shim rods, in thermal reactors.

1. A systematic treatment of the effect of burnable poisons of various concentrations and cross sections in thermal reactors has been given under simplifying assumptions.
2. The conditions for optimum combinations of fuel and burnable poisons have been indicated, such as to obtain maximum endurance and fuel utilization with a given amount of mechanical shim control. Conversely for a specified endurance the same conditions can be applied to minimize fuel loading and mechanical shim control.
3. In order to obtain optimum gains from the use of burnable poisons it is necessary to utilize fuel with lower concentrations of impurities than in reactors not utilizing burnable poisons.

TID-7532 (Pt.1)-23

Maienschein F C, et al.
EXPERIMENTS WITH CONTROL RODS AND VOIDS IN A POOL-TYPE REACTOR,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 14 pp. (5 refs).

Experimental data are presented in summary form only for (a) fuel removal, (b) poison plate addition and (c) water displacement by air in the core of the Oak Ridge National Laboratory Bulk Shielding Reactor. Fuel removal and poison addition led to uniformly negative coefficients of reactivity but the removal of water from the center of the core gave rise to a positive coefficient of reactivity. Measurements of reactivity changes were made by comparison with control rods calibrated by either the "period" method or by a distributed gold poison.

TID-7532 (Pt. 1)-24

Voorhis A D and Ryan T M
INVESTIGATION OF ABSORBING MEMBRANES IN SLAB REACTORS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 13 pp. (6 refs).

Absorbing membranes of Cd and of Au have been studied in a slab critical assembly. Experimental information includes critical dimensions and neutron activation traverses through each assembly perpendicular to the membrane. The critical assemblies were analyzed with a one-dimensional group diffusion code which computed neutron multiplication and flux distribution. A method for taking account of the absorbing membrane in such a calculation is described. The results of the calculation indicate that over 90% of the reactivity worth of the membrane can be accounted for by this method.

TID-7532 (Pt. 1)-25

Thie J A
CHEMICAL CONTROL EXPERIENCE IN BOILING REACTORS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 8 pp. (5 refs).

The use of boric acid in the boiling power reactors, Borax II, Borax III, and EBWR, is discussed. In all reactors its use contributed to understanding the reactor's physics. For Borax III chemical control was a necessary shim, since its control blades lacked sufficient strength in the cold, clean reactor. Methods of addition and removal developed, as well as methods of concentration measurement, were quite satisfactory. The amounts of boric acid used typically were found to have some influence on the characteristics of power operation.

TID-7532 (Pt. 1)-26

Metcalf D R
CENTRAL CONTROL ROD CALCULATIONS FOR SPERT REACTORS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 5 pp. (5 refs).

Control rod worth values are given for central transient rods in SPERT-I and SPERT-III reactors. The blade and cross-type shapes are converted into equivalent cyclinders by using the method described in KAPL 1336. Five different methods are described and applied to both reactors. The most reasonable value on physical grounds was then compared to the experimental value for SPERT-I. Calculations show that for the equivalent cylinders described here the control rod worth of a water-filled rod is at least twice the worth of a hollow-cylinder type rod. Also in SPERT-III, going from 68^{o} to 650^{o}F increases the control rod worth considerably.

TID-7532 (Pt. 1)-27

de Boisblanc D R
SOME CONTROL ROD STUDIES AT THE MTR,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D.C., October (1957), 3 pp.

The purpose of these comments is to present some of the experiences with reactor control elements at the MTR site. The first part of the discussion concerns the control elements of the Reactivity Measurement Facility. The second part is concerned with a report of a reversal of the reactivity versus distance-moved relationship in the MTR beryllium shimrods. The first discussion was deemed to be of interest to this group because it represents data on some unusual control rod designs and quantitative evaluation of their interactions with each other in the RMF. The second is deemed appropriate because it bears upon the general problem of adequate control element design which is of course of prime interest to those present.

TID-7535

Harrer J M, Barnes A H and Novich M
PAPERS PRESENTED AT THE TECHNICAL BRIEFING SESSION HELD AT ARGONNE NATIONAL LABORATORY, MAY 27 AND 28, 1957--BOILING WATER REACTOR PROGRAM, Argonne National Laboratory, Lemont, Ill., October (1957), 161 pp. (18 refs).

This report is a series of papers presented on the EBWR, a boiling water reactor. A general discussion outlines the design problems and operating concepts of a boiling water reactor. The economic aspects of the EBWR are discussed. Special papers are presented on the pressure-vessel design, fabrication, and installation. The core structure and fuel handling system are outlined. Physics experiments, control rod drives, power controls, instrumentation, plant equipment, leakage, water treatment, and safety provisions are discussed. There are separate papers on program planning for civilian power reactors, experiments with oxide fuels and fuel elements, and the preliminary design of the Argonne Boiling Reactor Facility.

TID-7539-11

Whitelaw R L
THE OUTLOOK FOR IMPROVEMENTS IN PRESSURIZED WATER REACTORS FOR MARINE PROPULSION,
Paper Prepared for a Symposium--Nuclear Powered Ships For American Ship Operators--July 30, 1957, Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 5 pp.

53

In the preparation of the proposal to undertake the first merchant ship reactor we indicated certain steps by which a pressurized water reactor in a 40,000 ton tanker might approach a competitive position with conventionally powered tankers. In the space of one year many more areas of improvement have appeared, some of which are under active development; at the same time the size and power required in the field of merchant ships, especially tankers, has increased along with the cost of fueling them. Hence, it is our considered opinion that the pressurized water reactor holds sufficient promise of improvements in the reactor art to be favored as the type of power plant most likely to meet the needs of nuclear merchant ships. It is most likely to be the first to offer comparable economics to operators of modern large ships, both passenger and cargo.

TID-7539-12

Brous C J
SUMMARY REPORT OF A CLOSED CYCLE BOILING WATER REACTOR FOR THE PROPULSION OF A MERCHANT SHIP,

Paper Presented at a Symposium--Nuclear Powered Ships For American Ship Operators--July 30, 1957, Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 39 pp.

The intent of this report is to summarize the salient engineering and economic characteristics of a nuclear tanker powered by an AMF Closed Cycle Boiling Water Reactor.

TID-7539-13

Gimera Ralph J
ORGANIC COOLED AND MODERATED REACTOR APPROACH TO MARINE PROPULSION,
Paper Presented at a Symposium--Nuclear Powered Ships For American Ship Operators--July 30, 1957, Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 13 pp.

This paper covers the use of such a reactor in merchant shipping. Included are descriptions of the ship, the reactor, fuel elements, control rods, control system, shielding, heat transfer system, fuel handling system, propulsion system and a safety summary.

TID-7539-14

Fahrner T, et al.
SUPERCRITICAL WATER REACTOR POWER PLANTS,
Paper Presented at a Symposium--Nuclear Powered Ships For American Ship Operators--July 30, 1957, Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 9 pp.

The pressurized water reactor, with its well-defined technology, is limited to rather low steam conditions and therefore a rather low overall thermal efficiency. If water at supercritical conditions of pressure and temperature were utilized as the coolant for a pressurized water reactor, it would become possible to increase the gross thermal efficiency of a plant from approximately 29% to perhaps 40%. This would result in an approximate one-third reduction in fuel costs.

This paper discusses the possibilities of using supercritical water as such a coolant and moderator.

TID-7539-16

Jarvis Theodore
GAS-COOLED REACTOR RESEARCH AND DEVELOPMENT,
Paper Presented at a Symposium--Nuclear Powered Ships For American Ship Operators--July 30, 1957, Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 2 pp.

This paper covers some possible problems of design of a gas-cooled reactor as these designs affect safety.

TID-7539-17

Thompson W I
GAS-COOLED REACTOR CONCEPTS,
Paper Presented at a Symposium--Nuclear Powered Ships For American Ship Operators--July 30, 1957, Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 11 pp.

This paper discusses in a broad sense the design characteristics of gas-cooled reactors including their efficiencies and economics.

TID-7548

FAST REACTOR INFORMATION MEETING,
Presented by the USAEC, Participants: Argonne National Laboratory, Los Alamos Scientific Laboratory, and Power Reactor Development Co., November 20, 1957.

This report covers: Nuclear Analysis of the Critical Experiments with ZPR-III, LAMPRE I, EBR-II, Enrico Fermi Reactor, Fuel Element Design, EBR-II Fuel Cycle, Molten Plutonium Fuel Development, Na Technology, Na Pumps, Na Piping System Components, Heat Exchangers, and Steam Generators, High Purity Sodium Systems, Advanced Plutonium Reactor Concepts, Fluid Fuels, Pu-U Alloy Metal Systems, Fuel Element Concepts, Fuel and Blanket Process Development, Coupled Fast-Thermal Reactor.

TID-7549 (Pt.1)-1

REACTOR SAFETY CONFERENCE,
Sponsored by American Nuclear Society, Atomic Industrial Forum, USAEC, New York, N.Y., October 31, 1957, 44 pp.

This document consists of four papers presented at the Reactor Safety Conference in October 1957. The titles of the paper presented are:

AEC Licensing Policies and Procedures with Regard to Reactor Safety

Technical Requirements for an AEC Safeguard Report

AEC Reactor Safety Experimental Program

The Role of the Advisory Committee on Reactor Safeguards

Preliminary safeguards and studies necessary for AEC licensing are discussed in detail.

TID-7564-1

Ritchie J S
INTRODUCTION TO THE KE-ACF GAS-COOLED NUCLEAR POWER PLANT,
Assistant Project Manager, Kaiser Engineering, Oakland, California. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 13 pp.

The design parameters for the various KE-ACF designs are outlined and a summary of the design features to be covered in detail at this symposium is presented.

A description and comparison of the preliminary design parameters and cost estimates are made for two power plants using CO_2 cooled graphite moderated reactors - one designed for natural uranium and the other designed for approximately 2% enriched uranium. Enrichment permits use of higher-temperature fuel element materials and also allows a smaller core volume. The resulting higher reactor outlet temperature (1000° compared to 800°F), reactor inlet pressure (400 compared to 285 psia), and average specific power, (10.3 compared to 2.4 mw/M. T.), along with higher fuel burnup (10,000 compared to 3000 mwd/M. T.), account for the lower power cost of 13.6 mils/kwhr for the enriched plant compared to 15.7 for the natural plant.

A general description of the projected prototype helium-cooled GCPR is given.

TID-7564-2

Kintner L L, et al.
THE METHOD FOR THE OPTIMIZATION OF A HELIUM-COOLED GRAPHITE MODERATED REACTOR POWER PLANT,
ACF Industries, Inc., and Kaiser Engineering, Oakland, California. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 35 pp. (3 refs).

The optimum combination of the major design parameters was determined for the large scale helium-cooled reactor power plant presently being designed by ACF Industries, Inc. and Kaiser Engineers. The basic parameters of the optimum plant including the outlet gas temperature and maximum specific power become the design basis for the Helium Cooled Prototype GCPR. The purpose of the prototype is to demonstrate the parameters of the optimum plant and to provide engineering, construction and operating experience applicable to the optimum plant.

This paper gives the method and results of the optimization analysis.

TID-7564-3

Wood P M
PHYSICS OF THE PROTOTYPE ENRICHED GCPR,
ACF Industries, Inc., Washington, D.C. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 4 pp. (3 refs).

In the physics analysis of the prototype Enriched Gas-Cooled Power Reactor the usual calculations of lattice parameters, reactivity lifetime, and control rod worth have been made. Some of the results which most affect the operating characteristics of the core are presented here.

TID-7564-4

Miller R S, et al.
DESIGN BASIS FOR THE PEGCPR FUEL ASSEMBLY,
ACF Industries, Inc., Washington, D.C. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 8 pp.

The development of ceramic uranium dioxide fuel is discussed. The design limitations and parameters are given. The requirement for containment of fission products within the fuel elements is explained and the design of the container for the fuel element is reviewed. The helium-cooled partially enriched uranium dioxide fuel elements and fuel assemblies are described, and the method of estimating their lifetime is presented.

TID-7564-5

Rulien F R
REACTOR CORE STRUCTURE OF THE PEGCPR,
ACF Industries, Inc., Washington, D.C. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 7 pp.

The graphite core structure is described and the bases for the selection of the more important materials are discussed. The operating conditions are given and the effects of these conditions on the design of the core structure are reviewed.

TID-7564-6

Perry P I
REACTOR HAZARDS,
ACF Industries, Inc., Washington, D.C. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 9 pp. (7 refs).

The hazards resulting from various assumed accidents and component failures have been examined for the prototype natural uranium and partially enriched uranium gas-cooled power reactor systems.

In general, the hazards associated with both types of reactors are similar. Both systems are characterized by large core heat capacities and relatively slow control rod withdrawal rates. These characteristics combined with the prompt negative temperature coefficient of reactivity of the fuel makes both reactors stable to power and temperature transients. The major difference in the two reactor systems is the presence of the chemically reactive fuel element materials, metallic uranium and Magnox, in the natural uranium system.

TID-7564-7

Young H D
REACTOR PRESSURE VESSEL AND CHARGE MACHINE,
Kaiser Engineering, Oakland, California. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 20 pp. (references).

A comparison is given of the dimensions of the pressure vessels for the nuclear power reactors in service and under construction in the United Kingdom and the vessel designs of KE-ACF.

The prominent problems considered in the designs of the KE-ACF pressure vessels are discussed, including the selection of sizes and configurations, nuclear heating, induced radiation, radiation damage, brittle fracture probability, seismic stability and requirements in addition to those of the ASME Code.

The charge machine is described in some detail and its versatility is illustrated by a typical sequence of operations.

TID-7564-8

Fieser G W
SERVICE MACHINE AND CONTROL ROD DRIVES,
ACF Industries, Inc., Washington, D.C. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 12 pp.

A description is given of the service machine, including its approximate size and operating functions. The control rod drives and their components are discussed. The operations of the entire drive mechanisms are briefly described.

TID-7564-9

Ernst J P
NON-NUCLEAR MECHANICAL COMPONENTS,
Kaiser Engineering, Oakland, Calif. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 9 pp.

The salient features of the helium prototype reactor coolant and steam systems are described. Criteria for the selection of the various components are discussed, and a brief description is given of the gas purification-vessel cooling system.

The basis for selection of the steam cycle is given along with pertinent information on the steam generators, turbine and auxiliaries, and plant control.

TID-7564-10

Fraas A P
THE ORNL GAS-COOLED REACTOR DESIGN,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 19 pp.

This paper has been prepared to present the major features of the ORNL CGR-2; there are so many facets to the problem that it is not practicable to present a thorough exposition of the design in the time available. The details of the design and the basis for the major design decisions are contained in ORNL-2500 (which contains 764 pages). The emphasis in this paper will be on the major points of similarity and difference between the British designs and the GCR-2.

TID-7564-11

Manly W D and Coobs J H
MATERIALS SELECTIONS AND DEVELOPMENT WORK,
Metallurgy Division, Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 26 pp. (9 refs).

The selection of the fuel, fuel capsule, and pressure vessel and related structures for the Oak Ridge National Laboratory gas-cooled reactor (GCR-2) is reviewed. Recent development work in support of the design of the forty-megawatt gas-cooled prototype reactor is also discussed, including the development of an improved fabrication process for uranium dioxide (UO_2) fuel pellets and testing of the fuel capsule material. Preliminary results from fuel irradiation tests are presented, and the variables to be studied in the Fuel Capsule Irradiation Program are discussed.

TID-7564-12

Trauger D B
MATERIALS COMPATIBILITY AND FUEL ELEMENT TEST PROGRAM,
Reactor Projects Division, Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 20 pp.

Engineering experiments to evaluate materials compatibility for the ORNL helium-cooled GCR-2 design effort were begun in December of 1957. More recently the program has been extended to include GCPR requirements. Metals and alloys of interest as possible materials of construction for a gas-cooled reactor and reactor grades of graphite are heated together in vessels containing static helium or in helium filled natural convection and forced convection loops. From these tests, measures of the inertness of various test specimens to the gaseous impurities evolved from graphite on heating are obtained. TSF and AGOT grades of reactor graphite have been used in both types of test stand to obtain a comparison of their gas impurity contents and degassing rates. The thermal convection loops were designed with a cold leg to obtain evidence of carbon mass transfer. Since the reaction kinetics are a function of the partial pressure of the gaseous impurities, the first equipment was simplified by establishing test pressures well below those for the reactor. Sampling equipment is provided in all test equipment for removal of gas periodically for mass spectrometer analysis. Two natural convection tests have been designed for operation at CGPR pressures to verify this assumption and to test fuel rod assemblies under external pressure where can collapse may occur.

TID-7564-13

Baker D E
GRAPHITE STUDIES FOR THE GAS-COOLED REACTOR PROGRAM,
Hanford Atomic Products Operation, General Electric Co., Richland, Wash. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 7 pp. (5 refs).

The rate of oxidation of graphite by carbon dioxide depends upon a number of variables which include the graphite temperature, radiation intensity, gas composition, flow rate, and pressure. Physical properties of the graphite which change the extent of surface area available for reaction also affect the rate of oxidation. Coated graphites, inhibitors

or impermeable graphites which would limit oxidation to an acceptable value in an advanced gas-cooled reactor are needed. A basic program for the study of the reactions of gases with graphite includes thermal reaction studies and irradiation induced reaction studies. An essential facility in the over-all study of gas-graphite reactions is a recirculating gas loop which will allow proof testing of promising materials and will aid in setting limits on the variables that affect the CO_2-graphite reaction. Although coolant graphite reactions are of primary importance, radiation damage to graphite cannot be neglected. Graphite has been observed to expand when irradiated at temperatures below 300°C and to contract at higher irradiation temperatures. The accumulation of stored energy in the cooler regions of reactors and the decrease in graphite strength as a result of oxidation must also be evaluated.

TID-7564-14

Robinson S T and Benenati R F
A HIGH TEMPERATURE - GAS CYCLE PEBBLE BED FOR CENTRAL STATION USE,
Sanderson & Porter, New York, N.Y. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 23 pp.

A high temperature - gas cycle Pebble Bed Reactor is described together with the specific design and economics of a 125 eMW central station power plant. The nuclear characteristics of the system are presented together with a discussion of fuel cycles, fuel element types and development problems.

TID-7564-15

Roy G M and Valerino M F
DESIGN CONCEPT FOR A GAS-COOLED, PRESSURE TUBE D_2O - MODERATED REACTOR,
General Nuclear Engineering Corp., Dunedin, Florida. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 8 pp.

The design concept for the ECNG-FWCNG gas-cooled project includes these key features:

a. The reactor is of the pressure tube type.

b. It is cooled with CO_2.

c. The moderator is heavy water.

The attainment of high gas temperature permits the utilization of an efficient steam cycle. Net electrical output of the prototype will be 50 megawatts; of the large-scale reactor, 200 megawatts.

TID-7564-16

Heacock Harold W
PARAMETRIC STUDIES OF THE GAS-COOLED REACTOR CONCEPT
Hanford Atomic Products Operation, General Electric Company, Richland, Wash. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 8 pp. (3 refs).

Generalized parametric studies of the gas-cooled, graphite-moderated power reactor concept have been performed at Hanford. These studies included consideration of capital charges, fuel cost, and operating expense for a number of process variables. Among the items considered for their effect on unit electrical power cost were the following: coolant gas selection, fuel enrichment, reactor thermal rating, power recovery cycle, coolant outlet temperature and reactor differential temperature, lattice geometry and specific tube power.

Subsequent to the completion of the initial studies, additional parametric studies of the reactor core configuration were performed. In these analyses attention was given to the effects upon relative unit power cost, for the more optimum cases, of the following variables: moderator-to-fuel ratio, active zone length-to-core diameter ratio, specific tube power, process channel flow area ratio, and reactor coolant differential temperature.

The study results obtained are felt to be generally valid for comparative purposes, but should not be used as absolute values of unit power cost.

TID-7564-17

Bernsen S A, et al.
THE MARINE GAS-COOLED REACTOR PROGRAM,
General Atomic Division of General Dynamics Corporation, San Diego, California. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 61 pp. (11 refs).

The AEC is presently sponsoring several gas-cooled reactor projects that are aimed at developing and applying gas-cooled reactors to civilian usage. These programs all fall in one of two categories. The projects in the first category are concerned with building reactors that require very little extension of our present technology. Each of these projects will make important contributions by providing early operating experience and data.

The second category covers those projects that are aimed at advanced reactors and systems that will explore the full potential of gas cooling. This category differs from the first because it required a relatively large step in technology and thus a long range, ordered development in materials, heat transfer, radiation stability, and gas handling technology is necessary. Because the MGCR falls within the second category, it is desirable to build an experimental prototype rather than an operational unit. In this way the system can be designed to permit easy access for experimentation free from the interference of operational requirements.

Since the problems in the development of high-temperature gas-cooled reactors are common to all types, the knowledge and experience gained through the development of the MGCR reactor will not only be applicable to the maritime program but also the central station power reactor program.

This paper will explain the interest in the closed-cycle gas-turbine system for the MGCR and describe the present status of the program.

TID-7564-18

McGee James P
HIGH-TEMPERATURE SYSTEMS FOR NUCLEAR PROCESS HEAT,
Bureau of Mines, US Dept. of the Interior, Morgantown, W. Va. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 21-22, 1958, 19 pp. (2 refs).

Investigations are being conducted to determine the feasibility of using nuclear heat in chemical processing. The use of nuclear reactors to furnish high-temperature heat is a field that has not received as much attention as electric power production and propulsion.

As part of the Atomic Energy Commission--Bureau of Mines process heat reactor program, a system is being studied in which helium is used as a heat-transfer medium from the nuclear reactor to the chemical processing vessel. A vessel heated by electrical induction to simulate a nuclear fission source of heat has been designed and constructed and is undergoing preliminary testing.

Gasification of coal and reforming of hydrocarbons are promising uses for nuclear process heat.

TID-7564-19

Bender M
COST AS A DESIGN CRITERION,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 9 pp. (4 refs).

The entire approach to the design of nuclear central power stations is founded on the premise of low-cost power production. Unfortunately we are not yet able to distinguish those with high potential for low power costs from those with low potential. It is almost useless to examine advanced designs until one has a yardstick to measure these potentials. Thus, a method of comparative cost analysis for design work is essential.

In this brief presentation it is impractical to present a comprehensive technique for cost comparison. Further, it is hardly claimed that we at Oak Ridge National Laboratory have more than touched the surface of the problem. A vast amount of work is required, but we believe it highly important in making design evaluations. In this discussion three illustrations of cost considerations in design are presented. These are:

1. Capacity effects on power station capital costs
2. Effects of geometry on fuel element costs
3. Design standardization effects on nuclear power plant costs

TID-7564-20

Perry A M
ADVANCED DESIGN STUDIES,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 12 pp. (3 refs).

The purpose of advanced design studies, at the present stage of gas-cooled reactor development, is mainly to disclose those combinations of materials and operating parameters that show the greatest promise of yielding low cost electric power or of satisfying some other design criterion such as successful breeding. Our preoccupation with the reactor now under development has been such that not a great deal of advanced design work has yet been undertaken at the Laboratory. A few rather well-defined studies have been carried out, and of these I should like to mention three: an investigation of the breeding capabilities of graphite-moderated, gas-cooled reactors, a brief study of high-pressure systems, and a nuclear gas engine for maritime applications. In addition a study of the general advantages and disadvantages of reactors with unclad fuel elements is underway, but not yet completed.

TID-7564-21

Cottrell W B
RELEASE OF ACTIVITY FROM VARIOUS GCR SYSTEMS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 15 pp. (18 refs).

As materials technology is pushed more and more in an attempt to reduce power costs, the hazards associated with gas-cooled reactors invariably increase. There are three different, although not necessarily independent, parameters which, as their values are increased in any particular design, tend to make that reactor more hazardous than it would be otherwise. These three are:

1. Operating temperature
2. Power density
3. Activity in coolant

These are discussed in detail.

TID-7564-22

Coobs J H
ADVANCED MATERIALS DEVELOPMENT,
Metallurgy Division, Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21-22, 1958, 9 pp. (6 refs).

The materials problems associated with the design of advanced gas-cooled reactor systems are discussed, and a number of materials combinations are evaluated. Preliminary results of current development work on fuel elements and capsule materials are presented. Three of the most favorable materials combinations are selected and proposed for further study.

TID-8003

Boardman Brewer F
GAMMA FACILITIES AT THE MATERIALS TESTING REACTOR,
Technical Information, Phillips Petroleum Co., Idaho Falls, Idaho, January 1956, 3 pp.

Widespread interest in the beneficial effects of gamma radiation on various commercial products, and as a means of studying and improving industrial processes has emphasized the need for a high-flux exposure facility where educational, commercial, research, and industrial organizations may carry out experiments without obtaining a security clearance. Two radiation facilities, using gamma sources of spent MTR fuel elements immersed in a water shield, have been provided in a building adjacent to the Materials Testing Reactor. Fluxes up to 20 million roentgens per hour are available at a very nominal cost. Only basic health-physics instrumentation is provided as a part of the facilities. Additional test and measuring equipment must be supplied by the experimenter. Use of the gamma facilities is available on a first-come, first served basis, and is authorized for experimental purposes only.

TID-8016

Perleberg C N
CONSTRUCTION OF FACILITIES FOR RADIOACTIVE WORK,
Technical Information Service, AEC, Washington 25, D.C., February (1958), 7 pp.

The construction of facilities to unlock the secrets of atomic power has been costly. Because of prohibitive costs and security requirements, the government has been the prime force behind the research and development of this new power.

Some of the requirements of reactor design for safe operation in populated areas and the design of a spherical container and its contained facilities are discussed. Specific reference is made to the construction of the Knolls Atomic Power Laboratory (KAPL). The disposal of low level waste is mentioned.

TID-10048

Jurney E T, et al.
THE LOS ALAMOS FAST PLUTONIUM REACTOR,
Los Alamos Scientific Laboratory, University of California, Los Alamos, N.M.,
Contract No. W-7405-Eng-36, May (1954), 144 pp.

This report attempts to record a complete description and fabrication history of the Los Alamos Plutonium Reactor. Much of what is described is now only of historical interest, however, since the reactor was completely dismantled in the Spring of 1953.

The Los Alamos Fast Plutonium Reactor is a low-power reactor built primarily (1) to demonstrate the feasibility of a reactor operating on unmoderated or "fast" neutrons, and (2) to serve as an experimental facility. The operating power level of 25 kw produces a fast neutron flux of approximately 4×10^{12} n/cm^2-sec. The reactive region consists of a lattice arrangement of metallic plutonium fuel rods surrounded by normal uranium reflector material and cooled by flowing mercury. Experimental facilities consist of numerous fast neutron ports and a graphite thermal column. Construction of the reactor was begun in December 1945, and full power operation was first attained in March 1949.

TID-10102

Maienschein F C
A HAZARDS SUMMARY FOR ROUTINE OPERATION OF THE BULK SHIELDING REACTOR AT ONE MEGAWATT,

Oak Ridge National Laboratory, Oak Ridge, Tenn. Contract No. W-7405-Eng-26, December 20, 1954, 54 pp. (15 refs).

The Bulk Shielding Reactor (BSR) consists of an assembly of modifed MTR-type fuel elements suspended in a "swimming pool" filled with demineralized water. It has operated since 1951 at power levels up to 100 kw. This report, after describing the existing facility, suggests modifications which would permit part-time routine operation at 1 megawatt. Finally, the hazards associated with higher power operation have been considered.

UCRL-3414

Ruby Lawrence
A SUSPENDABLE PULSED NEUTRON SOURCE,
Radiation Laboratory, University of California, Berkeley, Calif.,
Contract No. W-7405-Eng-48, May 14, 1956, 15 pp. (6 refs).

A laboratory pulsed neutron source has been constructed which may be suspended above or below floor level. The accelerator system consists principally of an ion source of the cold-cathode Phillips Ion Gauge type, extractor and focus electrodes, and an air-cooled target electrode. A cascade rectifier power supply allows the target voltage to be varied up to 100 kv. During the pulse the ion source is capable of delivering 4 ma of current, of which half is monatomic. The arc is pulsed for 200 μsec at a repetition rate of 60 cps. The integrated yield produced on the target exceeds 6×10^5 neutrons per sec for the d-d reaction and 6×10^7 neutrons per sec for the d-t reaction. The pulsed neutron generator is characterized by the absence of critical adjustments in any of the parameters governing its operation.

UCRL-3687

Brobeck W M and Scalise D T
UCRL DESIGN DATA OF GENERAL INTEREST,
Radiation Laboratory, University of California, Berkeley, Calif.,
Contract No. W-7405-Eng-48, September (1957), 71 pp.

This document contains forty-eight data sheets which have been issued from time to time since 1946. The data sheets represent summarized information which has been found useful in design work at UCRL.

UCRL-4454

Hubbard Harmon W
KINETICS OF SUBCRITICAL ASSEMBLIES,
Radiation Laboratory, University of California, Livermore, Calif.
Contract No. W-7405-Eng-48, February 25, 1955, 10 pp.

The time behavior of a subcritical assembly of fissile material, including delayed neutrons, is investigated. A normal mode source is turned on at $t = 0$ and the neutron population calculated as a function of time. For multiplications small compared to $1 + 1/\beta$, (135 for U^{235}) the exponential period is approximately the characteristic fast period $\tau / 1 - k$. For multiplications large compared to $1 + 1/\beta$, the period is slow $M \beta / \lambda$, and for intermediate cases, the results are plotted.

UCRL-4891

Frost Frederick E
RADIOACTIVE WASTE PROCESSING AND DISPOSAL (1950-1957) - BIBLIOGRAPHY,
University of California Radiation Laboratory, Livermore, Calif., May 6, 1957,
23 pp. (references).

This bibliography consists of reports compiled from the AEC Library Card Catalog. Only the classified and unclassified report literature is included. For the published literature the reader is referred to an unpublished paper by M. Cason (UCRL-Livermore Library).

Radioactive Waste Disposal, April 25, 1957. All progress reports covering the work have been omitted in order to exclude a large amount of duplicate information which is usually found in more detail in topical reports. For information prior to Jan. 1, 1950 it is suggested that the reader refer to TID-3008 - Radioactive Waste Processing and Disposal, H. E. Voress and Fred E. Croxton, Aug. 1, 1951 (Secret). The references are arranged by report number under one of the following:

I. Disposal of Wastes

II. Processing of Wastes

UCRL-4919

Radcliffe John B, Jr.
THE LIVERMORE POOL TYPE REACTOR (LPTR),
University of California Radiation Laboratory, Livermore, Calif.
Contract No. W-7405-Eng-48, July (1957), 59 pp. (references).

The LPTR is a tank-type thermal, heterogeneous research reactor facility at the Livermore site. The light-water moderated and cooled reactor core will generate a peak flux in excess of 10^{13} n/cm^2-sec at its initial operating power of 1 MW. Access to the flux is provided by a variety of experimental facilities, including 6 horizontal beam tubes (the largest almost 13 in. in diameter), 2 thermal columns (one largely removable to provide a high fast flux within an associated cave-like irradiation cell), and 3 pneumatic tubes (one provides access to a thermal flux trap in the center of the core). These, combined with a number of other irradiation ports, are intended to make the reactor a versatile, flexible research tool, available to all groups within the UCRL research program.

The LPTR design calls for a core containing roughly 4 kg of U^{235} in fuel elements of the MTR type, arranged within a 5 by 7 element grid configuration which also provides space for a reflector (both graphite and beryllium are available). Aluminum is the primary structural material in the core, and in the closed circuit cooling system. A compact biological shield is achieved through use of magnetite concrete. The reactor core is controlled by 4 boron-carbide shim safety rods and a stainless steel regulating rod, with conventional console control instrumentation. Total containment is emphasized in the reactor housing - an all-steel, air-tight structure which is connected to adjacent labs and the control room by an airlock.

WADC-TN-55-302 AD-99561

Atkins Marvin C, 1/Lt. (USAF)
ACCESSORY EQUIPMENT AND PROCEDURES FOR USE OF A 1500 CURIE COBALT-60 GAMMA-RAY SOURCE,
Wright Air Development Center, Wright-Patterson AFB, Ohio, April (1956), 13 pp.

The Materials Laboratory is using a 1500 curie cobalt^{60} source to investigate the effects of gamma radiation on materials. The source is a cylinder, 1.78 in. ID x 2.31 in. OD x 13.5 in. long. It is shielded by a lead container which is mounted on a table behind a concrete block wall. A rotating-beam hoist is used to change samples. Other items of accessory equipment include specialized plugs for the container, additional sample canisters, and a cooling system.

Measurements have been made of scattered radiation from the source. A standard operating procedure for use of the source has been established. This procedure has significantly reduced the probability of personnel exposure to harmful radiation.

WADC-TR-55-446

Sykes Paul J, Major (USAF (Editor))
PRELIMINARY SUMMARY REPORT ON THE PROPOSED AIR FORCE NUCLEAR ENGINEERING TEST FACILITY AT WRIGHT AIR DEVELOPMENT CENTER,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio,
Contract No. AF33-(616)-3018, September (1956), 356 pp. (40 refs).

This report presents a preliminary summary report on the proposed Air Force Nuclear Engineering Test Facility.

WADC-TR-56-452

Atkins Marvin C, 1/Lt. (USAF)
DESIGN OF A HIGH-INTENSITY GAMMA IRRADIATION FACILITY,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December (1956), 19 pp.

Construction plans have been prepared for a gamma irradiation facility capable of handling 100,000 curies of cobalt^{60}. In a facility built according to these plans, the radioactive source would be stored in a water well located in a 12 x 12 foot irradiation room. The source would rest on a platform in the well and be lifted up into the irradiation room for all experiments. The facility would be built underground with almost all shielding being provided by the natural earth. Normal laboratory utilities are provided in the plans, with valves and switches located on a control panel in an adjacent building. A closed circuit television system would be installed for viewing of experiments with the source in the operating position. Experimental apparatus would be equipped with suitable instruments so that general purpose manipulators would not be required. Six construction drawings are included in this report.

WAPD-2

Siegel Sidney
LECTURE SERIES ON ELEMENTARY REACTOR THEORY,

Atomic Power Division, Westinghouse Electric Corporation, P.O. Box 1468, Bettis Field, Pittsburgh 30,Pa., September-December (1949), 141 pp.

This report concerns itself with the elementary theory of nuclear reactors in which the fissions are primarily produced by neutrons of thermal energy, and in which the fissionable and other materials are homogeneously dispersed. In addition, the primary emphasis will be on a reactor suitable for producing power on a naval vessel, and the examples discussed are chosen with this in mind.

This report discusses the critical condition in a finite assembly, containing fissionable and other materials, which is dependent on geometry, the multiplication constant and the migration length. Also discussed are: neutron reactions; life history of a neutron in a reactor; diffusion of neutrons; pile equation and its solution; slowing down of neutrons; reactor kinetics; and control rods.

WAPD-142 (Navy)

Henry A F
COMPUTATION OF PARAMETERS APPEARING IN THE REACTOR KINETICS EQUATIONS, Bettis Plant, Westinghouse Electric Corporation, Pittsburgh, Pa., Contract No. NObs-67500, December (1955), 55 pp.

The reactor kinetics equations are obtained from the time dependent transport equation by assuming separability of the time dependence and applying suitable adjoint functions. The quantities reactivity, effective delayed neutron fraction and prompt neutron lifetime are defined by this process in terms of integrals of directional fluxes and adjoint functions over angle space and energy. A reduction to diffusion theory and group theory is then carried out, and techniques for computing reactivity coefficients and effective values of the delayed neutron fractions are discussed.

WAPD-BT-4

REACTOR PHYSICS AND MATHEMATICS,
The Bettis Technical Review, Vol. 1, No. 4, Bettis Plant, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, October (1957), 113 pp.

The purpose of the Bettis Technical Review is to report to industry on technology developed at the Bettis Plant. This publication includes twenty-two papers as listed below.

Reactor Theory and Experimentation

1. Review of Methods Used in Control Rod Analysis for Reactor Design at Bettis Plant-- A. F. Henry
2. Two-Dimensional Burnup of a Cell--W. D. Kimball
3. Resonance Capture in Heterogeneous Systems--S. Stein
4. Half-Height Cadmium Slab--R. S. Halgas and M. Bender
5. Synthesis of Three-Dimensional Power Distributions for a Nonuniformly Depleted Core--R. R. Schiff
6. Synthesis of Three-Dimensional Power Shapes - Flux-Weighting Technique--J. E. Meyer

7. Nuclear Design of a Fuel Assembly for an Irradiation Proof Test--S. Sandhaus
8. Analysis of a Heterogeneous Critical Assembly--R. J. Breen
9. The Use of the Equivalent Bare Core Model for Calculating the Criticality of Slab-Type Reactors and a Comparison to Experiment--R. S. Wick and J. D. Butler
10. Thermal Flux Depressions in Materials Containing Fuel and Boron-- R. J. Neuhold and G. F. Bogar
11. An Inverted Reactivity Effect--L. O. Herwig and E. R. Sanford
12. Thermal Equivalent Σ_p for Cadmium-Silver Control Rods--A. J. Calio
13. Changes in Reactivity Produced by Thermal Expansion of Extruded Polyethylene Fuel Tape--R. Christman
14. Construction and Operation of a Miniature Fission Counter--T. M. Ryan

Mathematics and Computations

1. A Lemma of Stieltjes--R. S. Varga
2. Calculation of Thermal Constants--H. J. Amster
3. Reactor Criticality and Nonnegative Matrices--G. Birkhoff and R. S. Varga
4. A Steady-State Thermal Analysis Code for the IBM-704 Computer--R. R. Schiff and W. M. Jacobi
5. Few-Group Fitted Parameters--P. A. Ombrellaro
6. A New Version of the Multigroup Fourier Transform Code for Calculation of Fast Group Parameters--E. Gelbard and H. Bohl
7. The WANDA Spatial Code--O. J. Marlowe and E. Gelbard
8. CANDLE - A One-Dimensional Few-Group Lifetime Depletion Code--E. M. Gelbard, et al.

WAPD-BT-5-1

Devine R F
HOW FUNCTIONAL REQUIREMENTS GOVERNED DESIGN AND ARRANGEMENT OF THE SHIPPINGPORT ATOMIC POWER STATION,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 8 pp.

Design of the reactor plant at Shippingport has been influenced by a number of factors. Some of the plant's functional requirements are discussed. A brief explanation of the interrelation of function and plant layout is given.

WAPD-BT-5-2

LaPointe J R and Brown R D
CONTROL OF RADIOACTIVE MATERIAL AT SHIPPINGPORT,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 15 pp. (7 refs).

Criteria are presented for the disposal of radio-active wastes from the Shippingport Pressurized Water Reactor. The design aspects involved in applying these principles to the radioactive disposal facilities are discussed. The types of wastes encountered at the plant and the processes developed are detailed.

WAPD-BT-5-3

Langlois C E
THE EXPENDED CORE FACILITY,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 13 pp. (1 ref).

It has been recognized for some time that there is much to be learned from a core after it has been taken out of operation. A plant is under construction at NRF, Idaho, which will be equipped to cut up and analyze cores as well as to prepare the fuel-bearing material for recovering of fuel by a chemical processing plant. This article gives a brief description of the reasons for and the design of that facility.

WAPD-BT-5-4

Cota S W and Green S J
BETTIS PLANT THERMAL AND HYDRAULICS LABORATORY,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 22 pp.

Bettis Plant is equipped with a Thermal and Hydraulics Laboratory to provide the design and development groups with design data and equations. Experimental boiling, experimental nonboiling, and theoretical studies are conducted at this laboratory. The laboratory's physical plant and method of operation are described.

WAPD-BT-5-5

McKeown W G
TRAINING OPERATING PERSONNEL FOR NUCLEAR POWER PLANTS,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 7 pp.

The training of personnel to operate nuclear power plants is a problem industry is beginning to face. The AEC licenses, regulates, and inspects the US nuclear industry and has set up training regulations which must be complied with. Qualifications and training required for all operating personnel are discussed.

WAPD-BT-5-6

Waldman L A
DESIGN AND OPERATING CHARACTERISTICS OF A BED FILTER FOR AN IN-PILE TEST FACILITY,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 12 pp. (2 refs).

An analysis of radioactive contamination in in-pile facilities containing defective fuel elements may be made through application of a full stream filter. A bed filter was designed to remove in-pile radioactive particles, including activity released from these defective fuel elements and crud formed by the corrosion of stainless steel surfaces, with a minimum of handling hazards. The basic components, testing, and operating characteristics of the bed filter are described.

WAPD-BT-5-8

Maxwell J R
DETERMINING PERFORMANCE CHARACTERISTICS OF A SATURATED STEAM PRESSURIZER FOR NUCLEAR POWER APPLICATIONS,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 6 pp.

Pressurizers are designed to insure that primary coolant remains subcooled during all plant operation even at the end of the reactor core life. Steady-state performance and change of power level operation effects over the lifetime of the core are discussed. A method of determining water levels that will permit maximum pressurizer performance and predict that performance is outlined.

WAPD-BT-5-9

Meyer J E
STUDY OF THE FORCE-DEFLECTION CHARACTERISTICS OF A BELLEVILLE SPRING,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 7 pp. (3 refs).

Calculated predictions of Belleville spring behavior based on simple theory can be misleading. A sample problem is developed in which this is the case. Sources of error are pointed out and the importance of considering in detail the method of load application is stressed.

WAPD-BT-5-10

Atherton R and Harman L H
HYDRAULIC TEST PROGRAM FOR REACTOR CORE COMPONENTS,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 7 pp. (1 ref).

Extensive preliminary hydraulic testing on reactor models is a much-used tool of reactor designers. Reduced-scale, actual-size, and scale-up models are used for various tests. A description of the general philosophy of model utilization is given, and the present and future test programs are outlined.

WAPD-BT-5-11

Busch J S and Carpenter J M
A REVIEW OF TWO-PHASE FLOW RELATIONS,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 7 pp. (37 refs).

In a loss-of-coolant-flow transient, calculation of heat removal is usually complicated by two-phase coolant flow. Natural convection with respect to required and available pressure drop correlations is considered. An approximate calculation procedure is suggested and a comprehensive survey of available literature is presented.

WAPD-BT-5-12

Busch J S
FORMAL HEAT TRANSFER SOLUTIONS FOR REACTOR DESIGN,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 9 pp. (1 ref).

Relatively simple formal solutions to heat transfer problems are important tools of the reactor designer. Two basic problems - the first considering a change of coolant temperature with time, the second considering a change of coolant velocity with time - their solutions, and the development of those solutions should be useful in approximating the effects of temperature changes within the reactor which might produce thermal shock, reactivity excursions, and core damage by loss-of-pumping-power transient.

WAPD-BT-5-13

Busch J S, et al.
TRANSIENT TEMPERATURE DISTRIBUTION IN PRESSURE VESSELS,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 5 pp. (4 refs).

An IBM-704 program called TURF-2 has been developed for determining the transient temperatures in bodies of revolution which have axial symmetry. The basic relaxation techniques, parameters, and physical constants employed are discussed along with preparation of input data. Outstanding advantages and limitations of the code are outlined.

WAPD-BT-8

Bettis Technical Review, Reactor Physics and Mathematics, Westinghouse Electric Corp., Contract No. AT-(11-1)-Gen-14, June (1958), 155 pp.

This document contains 21 papers which are listed below:

Tanner, J. M., "Conversion Ratio and its Time Dependence in a Simple Seed-Blanket Geometry"

Anderson, D. C., "Calculation of Buildup Factors for Infinite Plane and Line Sources"

Anderson, D. C., "'Comparison of Pebbles' Buildup Data to Experiment and Moments Method Results"

Horst, R. B., "Synthesis Methods in R-Z Geometry"

Ball, T. W., "Synthesis of Lifetime Power Distributions in R-Z Geometry"

Lorentz, W. N., "Synthesis of Three-Dimensional Power Shapes - Application of Flux-Weighted Synthesis Techniques"

Jones, L. L., Jr., "Empirical Determination of the Fast-Absorption Constant for Hafnium Control Rods"

Neuhold, R. J., "Fast Absorption of Hafnium and Cadmium-Silver Control Rods"

Halgas, R. S., "Hafnium Controlled Critical Assembly"

Stein, S., Sukasik, S. J., and Hellens, R. L., "Analysis of Slightly Enriched Uranium-Water Lattices"

Brown, J. R., "Critical Experiments on Water-Moderated Lattices of Slightly Enriched Uranium Dioxide (UO_2) Fuel Rods"

Klein D., and Smith, G., "The Measurement of Parameters in High Uranium Content Lattices"

Horst, R. B., "Criticality Calculations for the TRX"

Hopkins, G. R., and Jamieson, C. P., "Techniques of Reactivity Measurement"

Sanford, E. R., and DeAgazio, P. N., "Pile Irradiation of Fuel-Bearing Plastic Tapes"

Mikoleit, L. A., "Criticality Experiments Using Miniature Fission Counters"

Daum, L., "Electron Multiplier Neutron Detectors"

Kaufman, W. M., and Jeeves, T. A., "Transistor Logic Applied to Digital Pressure Control and Indication"

Johnson, S. O., "Simulation of Hot Channel Boiling"

Rose, R. P., and Johnson, S. O., "A Method of Evaluating Heat Transfer Simulation in Pressurized Water Reactors"

Gast, R., "On the Equivalence of the Spherical Harmonics Method and the Discrete Ordinate Method Using Gauss Quadrature for the Boltzmann Equation"

WAPD-MRP-69

TECHNICAL PROGRESS REPORT - PRESSURIZED WATER REACTOR (PWR) PROJECT, Westinghouse Electric Corp., Bettis Plant, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, August 23, 1957, 78 pp.

This report discusses system design and power plant component development of the PWR. Component developments discussed are prototype multiport sampling valve, primary system relies valves, and resistance thermometer seals.

Cores 1 and 2 are discussed under the heading reactor design. The progress of Core 1 assembly is outlined and a complete performance analysis of the core has been completed. Core 2 is in the planning stage and core support plate designs, control rod and shroud assembly tests, fuel assemblies, and performance capability of rods, tubes, and oxide assemblies are discussed.

The metallurgy and physics of Core 1 are discussed.

WAPD-MRP-70

TECHNICAL PROGRESS REPORT - PRESSURIZED WATER REACTOR (PWR) PROJECT FOR THE PERIOD AUGUST 24, 1954 TO OCTOBER 23, 1957,
Westinghouse Electric Corporation, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, (1957), 80 pp.

This report covers the progress of the PWR during the period from August 24, 1957, to October 23, 1957. During this period, the significant developments were: A pipe thread sealant which will not contaminate primary water and is suitable for cold nonradioactive liner up to 5600 psi was located; successful tests on a multiposition valve were completed; PWR Core 1 was successfully installed at Shippingport; tests were made on a full scale mock-up of the control rods to determine scram characteristics; core instrumentation was reviewed; nuclear design work was completed on several control rods for Core 2; air flow studies and plenem chamber designs were continued; effort was expended upon ceramic fuel elements and their radiation resistance; analysis on the performance of rods versus tubes versus plates in the blanket region of the core was completed; improved techniques for inspection of flat plates and fuel rods were perfected and corrosion standards were developed for these items; PWR Core 1 rod bundle irradiations continue; fission gas release in ceramic elements is reported; Core 2 elements have been tested at WAPD; bonding experiments on fuel elements are reported; corrosion data, irradiation and mechanical property data on Ag-15 In-5 and Cd control rod alloy confirm the suitability of this material for control rods; reactivity lifetime studies were started on Seed 2; the shutdown reactivity of Core 1 hafnium control rods was determined in the full scale critical facility mock-up; a complete set of current parameters for the PWR, including both plant parameters and core parameters is covered.

WAPD-MRP-71

Simpson J W (Manager)
TECHNICAL PROGRESS REPORT - PRESSURIZED WATER REACTOR PROJECT - FOR THE PERIOD OCTOBER 24, 1957 TO DECEMBER 23, 1957,
Bettis Plant, Westinghouse Electric Corporation, Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, 1957, 89 pp.

This report covers the activities of the personnel at the Pressurized Water Reactor during the period of October 24, 1957 to December 23, 1957. It was during this period that approval of the Hazards Committee of the AEC gave its final approval and criticality was achieved as was full power generation. Desensitization of the detectors in the Nuclear Instrumentation System was necessary because of greater fluxes than anticipated.

Work on Core 1 was completed and the installation accomplished. The design of Core 2 proceeded with investigations of the control rod shrouds, heat generation in the pressure vessel and thermal shields, scram timer, air flows and cladding failures.

Metallurgy work including X-ray diffraction analysis of UO_2, surface treatment of fuel element cladding for corrosion resistance, control rod alloy, investigation, and properties of UO_2 under varying conditions were completed.

Cold criticality studies and tests on Core 1 were completed and flux distributions in Seed 2 were calculated.

WAPD-MRP-72

Simpson J W (Manager)
TECHNICAL PROGRESS REPORT-PRESSURIZED WATER REACTOR (PWR) PROJECT - FOR THE PERIOD DECEMBER 24, 1957 TO FEBRUARY 23, 1958,
Bettis Plant, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, (1958), 58 pp.

This progress report covers plant and core engineering for the Pressurized Water Reactor at Bettis Plant, Pa. The plant engineering section covers power plant analysis and systems; power plant components and component materials and tests; materials, control mechanisms, and tests; and reactor and auxiliaries. Core engineering, metallurgy of core materials, and reactor physics are the subjects of the second section.

WAPD-T-432

Kaplan Stanley
EXPERIMENTAL TECHNIQUE FOR THE CALIBRATION OF REACTOR CONTROL DEVICES AND FOR THE DETERMINATION OF POWER LEVEL,
Thesis, Westinghouse, University of Pittsburgh, Pittsburgh, Pa., November (1956), 32 pp. (32 refs).

The calibration of the control devices of a nuclear reactor is analogous to the calibration of the regulating mechanism of any other type of scientific or engineering equipment, such as the calibration of governor. A complete calibration of a reactor control system, however, is more difficult than most calibrations because of the complexity and interdependence of reactor phenomena.

A control device for a nuclear reactor may take many forms. It may, for example, take the form of fuel or poison which can be added or removed from the reactor, or it may be a changeable reactor geometry, or a movable reflector. Most frequently the reactor control system consists of highly neutron absorbent control "rods" which can be inserted various distances into the reactor.

In order to clarify the nature of a control calibration problem, consider the calibration of a control rod. A complete calibration of a control rod consists of an answer to the question: "What is the reactivity change associated with any given motion of the control rod under any reactor condition?"

In accordance with this definition on the obvious experimental procedure is simply to bring the reactor to the desired condition, bring the control rod to the desired location, then give it the desired motion and measure the resulting change in reactivity. This simple approach is frustrated by a number of different effects. One example of the limitations is in the measurement of the total worth of a rod, that is, the reactivity change due to moving the rod from the fully-in to the fully-out condition. It may not be possible to pull the rod fully out in one step because the reactivity which would be added if this were done would be so large that an unsafe condition would result. In order to measure a total rod worth, if it is sizable, it is necessary to measure it a part at a time while adjusting the reactivity to a safe value by some other means. However, this amounts to changing the reactor condition. Thus it is not possible to measure the reactivity change of any motion under any condition but only of limited motions under limited conditions.

WAPD-T-442

Maharan A L
THE DESIGN AND CONSTRUCTION OF THE ENLARGED WESTINGHOUSE HOT LABORATORY,
Bettis Plant, Westinghouse Electric Corp., Pittsburgh, Pa., (1957), 19 pp.

This paper describes the construction of the Westinghouse Hot Laboratory Addition and the major items of equipment located therein. Some of the items described are the hot laboratory building, the high level cells, the decontamination room, a metallographic cell, the radiochemistry facility, the sample storage pit, and the laboratory ventilation equipment.

WASH-746

Baker W E and Allen F J
THE RESPONSE OF ELASTIC SPHERICAL SHELLS TO SPHERICALLY SYMMETRIC INTERNAL BLAST LOADING,
Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, November (1957), 43 pp.

This report presents the results of an analytical study of the reaction of an idealized nuclear reactor containment shell to internal transient loading which could be caused by reactor runaway.

The containment shell is assumed to be an elastic hollow sphere, and the transient loading is assumed spherically symmetric. A general theory of the response, valid for shells of any thickness, is developed. The theory is approximated for thin shells, and compared with experiment. The experiments corroborate the theoretical predictions.

WASH-747

Larson R J and Olson W
MEASUREMENT OF AIR BLAST EFFECTS FROM SIMULATED NUCLEAR REACTOR CORE EXCURSIONS,
Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland, September (1957), 51 pp.

Tests were conducted to evaluate methods of simulating on a small scale, the effect of nuclear reactor "runaway" on a containment shell surrounding the reactor. Reactor core vessels, simulated by small pressure tanks, were burst by chemical reactions of various rates, and the resulting pressure-time histories were recorded by piezo-electric air blast gages placed at various distances from the core. Results of 150 observations are tabulated and presented graphically. The test results were compared with existing blast data for chemical explosives and also with Brode's theoretical analysis of spherical blast waves. The use of an explosive, which provided the fastest reactive rate, proved to be the most practical means of simulating reactor core runaway.

ORGANIC CHEMICALS, INCLUDING FUELS, LUBRICANTS, AND OTHER PETROLEUM PRODUCTS

ORGANIC CHEMICALS, INCLUDING FUELS, LUBRICANTS, AND OTHER PETROLEUM PRODUCTS

AECD-3529 ORNL-1379

Blanco R E, Kibbey A H and Pannell J H
RADIATION STABILITY STUDIES: PART I - AQUEOUS ETHYLENEDIAMINE TETRA-ACETATE AND ACETATE SOLUTIONS; PART II - BECKMAN GLASS pH ELECTRODES, Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, September 22, 1952, 19 pp. (6 refs).

An investigation of the radiation stabilities of aqueous solutions of sodium ethylene-diamine tetra-acetate and sodium acetate was made using a 3000-curie Co^{60} source. It was found that the initial decomposition rate of the ethylenediamine tetra-acetate was 0.62 millimole per watt-hour of absorbed energy. The decomposition rate of the simpler acetate ion was not determined quantitatively, but the small changes in the physical properties of the solution indicated a negligible or very low decomposition rate.

A study of the behavior of standard-size Beckman type glass pH electrodes in a solution containing 0.36 curie of Ce^{144} - Pr^{144} activity per milliliter showed the useful electrode life to be of the order of two to eight days.

Ethylenediamine tetra-acetic acid, a chelating agent sold under the trade name Versene, has proved to be a valuable reagent for the separation of fission products at low radiation levels.

AECD-3711

Bolt R O and Carroll J G
SUMMARY EVALUATION OF ORGANICS AS REACTOR MODERATOR-COOLANTS, California Research Corp., Richmond, Calif., March 15, 1955, 9 pp.

Over the past several years, a modest research effort has been maintained on an investigation of organic compounds as possible reactor moderator-coolants. The purpose of this report is to summarize briefly the information presently available on certain organics as reactor moderator-coolants as an aid in the formulation of a program for further development of these materials for this use.

AECU-3077 ERI-1943: 4-41-T

Harmer David E
THE REACTION OF CHLORINE WITH AROMATIC COMPOUNDS UNDER INTENSE GAMMA IRRADIATION,
Engineering Research Institute, University of Michigan, Ann Arbor, Mich., Contract No. AT-(11-1)-162, May (1955), 30 pp. (81 refs).

The purpose of the program of investigation described below was to study the effect of gamma radiation on the chlorination of certain aromatic compounds. Chemical

reactions were carried out in the presence of gamma radiation from two cobalt-60 sources. One of these sources had a strength of approximately 200 curies, and the other about 3000 curies. Both were located in the Fission Products Laboratory of the University of Michigan.

Gamma radiation was found to be an outstanding promoter for the addition of chlorine to benzene. The reaction proceeded with such speed in the 200 curie source that it was necessary to dilute the reactant benzene with carbon tetrachloride in order to control the heat of the reaction, and to prevent the equipment from becoming clogged with solid reaction products. Radiation yields were of the order of 19,000 to 114,000 molecules reacted per 100 electron volts absorbed by the system. The product of the radiochlorination of benzene was found to be the several isomers of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane, the commercially important gamma isomer of which occurred to the extent of about 11 to 13%.

The radiochlorination of toluene proceeded rapidly, although not so fast as the benzene reaction. Most of the chlorine was consumed by addition to the ring, although substitution also occurred. The addition product was separated from other reaction products in good yields, and appeared to be similar to material previously reported to be formed in minor amounts during the photochlorination of toluene. The addition product was converted to known compounds.

A study of the initial reaction rates of the radiochlorination of toluene revealed that the addition and substitution reactions were both dependent upon approximately the 0.5 power of the radiation intensity, within the range of 7.9 to 28.4 kilorep per hour. The amount of dosage was calculated from ferrous sulfate dosimetry, using a conversion factor of 15.4 micromoles per liter-kilorep, where one rep corresponds to the absorption of 93 ergs per gram. The initial rate of addition was dependent upon the square of the chlorine concentration, while the initial rate of substitution was dependent upon the square root of the chlorine concentration, between 1.8 and 3.0 moles/liter of chlorine. The effect of temperature could not be determined with accuracy, but both the addition and the substitution reaction rates were increased by increasing temperature, after corrections for the changes in chlorine solubility had been applied. Long reaction chains were indicated in the toluene reaction, and the rapid addition reaction produced by the gamma irradiation appeared to be unique compared to other reported reactions of toluene. The partial kinetics of the reaction can be summarized by the equation:

$$R = -\frac{dc}{dt} = k_a I^{0.5} (Cl_2)^2 + k_s I^{0.5} (Cl_2)^{0.5}$$

Chlorobenzene was found to undergo a rapid addition of chlorine under gamma irradiation. Benzyl chloride, benzal chloride, and benzotrichloride, however, showed no reaction under the same conditions. Furthermore, the addition of small amounts of benzyl chloride to benzene or toluene produced a marked inhibition of the reaction when the mixtures were treated with chlorine under irradiation. Since a similar effect is not observed in the analogous photochemical reaction, the inhibition of the radiochlorination is very unusual. Oxygen gas was also found to inhibit both the addition and the substitution reactions. Possible explanations of the differences between the photochlorination and radiochlorination of the aromatic compounds are discussed.

AECU-3148

Bolt R O, et al.
RADIATION RESISTANT GREASES,
California Research Corporation, Richmond, Calif., Contract No. AT-(11-1)-174, June 30, 1956, 30 pp. (10 refs).

Lubricating greases were exposed to radiation with three purposes in mind:

1. To determine radiation level of damage for presently available commercial grease types.
2. To develop greases of enhanced radiation stability.
3. To gain insight into the mechanism of change.

Small samples (about 12 grams) were exposed to gamma radiation; included were six commercially available greases and two experimental types made from alkylbenzene fluids. The experimental greases retained consistency for a considerably higher dosage than the commercial products. All greases showed a period of softening followed by eventual hardening. The softening appears to result from attack on the gel structure. Eventual hardening is due to oil polymerization.

Four of the above greases were exposed to the reactor flux of the Materials Testing Reactor. In terms of consistency, decomposition was excessive after 5×10^{18} slow neutrons per sq cm except for the grease made with alkylbenzene which was still greaselike.

Samples of about 150 grams of ten different greases were exposed in the canal source of the Materials Testing Reactor. The greases included commercial types for reference purposes, commercial types containing special additives and experimental products. After radiation, standard grease tests were performed on the irradiated sample so that results could be compared with data on the unirradiated greases. Original bearing life was decreased by 2 to 20 fold after 6.5×10^{8} roentgens. Oxidation stability was severely impaired at this dosage, and low temperature torque was impaired to a minor degree. Evaporation, copper corrosion, and wear were not significantly changed by radiation.

Greases made from alkylbiphenyl and alkylnaphthalene showed excellent results in standard grease tests. After a dosage of 32×10^{8} r, the performance of the alkylnaphthalene grease was superior to that of commercial greases. Based on these results, the technical part of a proposed specification for a radiation resistant grease is included as Appendix III.

APEX-167

Calkins V P
RADIATION DAMAGE TO NON-METALLIC MATERIALS,
Aircraft Nuclear Propulsion Dept., Atomic Products Div., General Electric Co., 35 pp.

Practically any material will undergo some change in physical or chemical properties in a given radiation field because of the action of the radiation on the material. The degree of the change in any physical or chemical property of a material is a measure of its radiation damage. Radiation damage is a function of the nature and chemical configuration of the material, the particular physical or chemical property being measured, the general and specific type of radiation involved, and the total dosage of radiation received.

This report discusses the mechanism of radiation damage, radiation units of measurement, specific types of radiation damage on organic liquids and fluids, and service life of nuclear power plant components.

APEX-411

Pomeroy G W and Calkins V P
IRRADIATION TESTING OF ORGANIC LIQUIDS,
General Electric Co., Atomic Products Div., Aircraft Nuclear Propulsion Dept., Cincinnati 15, Ohio, Contract No. AF33(038)-21102, AT-(11-1)-171, August (1955), 42 pp.

This report summarizes the results of irradiation tests of organic materials conducted in the HB-2 facility of the LITR and in the electron beam of the GE-ANPD 2-Mev Van de Graaff accelerator. Several organic liquids capable of withstanding temperatures up to 650°F have been tested, and descriptions of the tests and typical data are presented.

A comparison of the data from the 300°F reactor irradiation tests indicated that alkylbenzene 250 was more radiation stable than alkylbenzene 350 on the basis of viscosity change and gas evolution rate as a function of dosage, but was not as stable as Dowtherm-A. When alkylbenzene 250 was subjected to reactor irradiation tests at 500°F, it was found that the physical property changes with radiation dosage were not markedly different from those measured in the 300°F tests.

In a search for liquids usable at 600°F, Van de Graaff data indicated that Pentalene 95, Pentalene 195, and number 290 showed stability at these temperatures. Of the three liquids tested to date, number 290 appears most promising. A study of hydrogen content and over-all radiation stability is given.

ASLE-58-LC-1

Carroll J G and Bolt R O
DEVELOPMENT OF RADIATION RESISTANT OILS,
California Research Corp., 576 Standard Ave., Richmond, California, October (1958), 6 pp. (12 refs).

The objective of this work was to develop oils of maximum radiation stability from readily available ingredients. Lubricants in three viscosity grades were made with alkylbenzenes containing selected polymers and additives. Each new oil was subjected to standard tests to determine if it met the specifications for presently used products made from mineral oils. The special oils complied with most requirements, and shortcomings were generally correctable. Both the special and conventional oils were irradiated under water in the Canal Gamma Source at the Materials Testing Reactor (MTR) in Idaho. Most conventional oils were damaged beyond usefulness at 10×10^8 roentgens (r). The alkylbenzene fluids still retained lubricating qualities after 50 to 70×10^8 r and remained fluid well above 100×10^8 r. These results prove the feasibility of making radiation resistant lubricants by this new approach.

ATS-tr-RJ-1613

Bakh N A and Saraeva V V
OXIDATION PROCESSES IN ORGANIC SYSTEMS UNDER THE ACTION OF IONIZING RADIATION,
Associated Technical Services, Inc., P.O. Box 271, East Orange, N.J., (1958), 11 pp. (28 refs).

Among reactions which take place under the action of ionizing radiations in organic substances, oxidative processes which occur during the irradiation of various systems in the presence of air attract particular attention. This is due to their wide distribution, the

possibility of their practical applications, and their great importance in radiobiological phenomena.

In the present article radiation oxidation of individual compounds by molecular oxygen under conditions when the radiation energy is directly absorbed by the molecules being oxidized, which are transformed into a reactive state as a result of ionization, excitation and decomposition into radicals are examined.

Data are presented on n-heptane, acetone, di-isopropyl ether, and di-isopropyl ether in aqueous solution saturated with oxygen.

BMI-125A-7

Rice L R, Lt.
NUCLEAR RADIATION RESISTANT LUBRICANTS - A REVIEW OF THE 125A FLUID AND LUBRICANT DEVELOPMENT PROGRAM,
WADC, Wright-Patterson Air Force Base, Ohio. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957.

This report presents a summary of current information on the state of the art of nuclear radiation resistant lubricant development. Data are given on the effects of gamma radiation on a number of commercial fluids and lubricants, with a discussion of potential problem areas to be expected in their use. Advanced materials for extremely high temperatures and radiation exposures are discussed, and the present status of availability and production is outlined.

Gamma radiation effects on a synthetic based aircraft instrument oil, a corrosion-preventive oil, and an internal combustion engine lubricating oil show the same trend as observed for similar materials in previous tests. The flash point goes down with increasing exposure, the neutralization number increases, gassing takes place, and corrosive action during the oxidation-corrosion test increases markedly with the increase in gamma dosage. Of the oils reported, the internal combustion engine oil showed the least change with irradiation, remaining essentially the same up to a dose of about 1×10^8 roentgens, whereas the instrument oil and the corrosion-preventive oil show serious changes as low as 1×10^7 roentgens.

Of the new base materials for use in extreme conditions of temperature and radiation, the aromatic ethers continue to show the most promise of usability. Relatively low melting compounds can be prepared that undergo minor change in 500°F oxidation-corrosion tests and form little coke at temperatures as high as 800°F. Radiation exposures of about 2×10^9 roentgens cause aliphatic hydrocarbons and diester materials such as di-2-ethylhexyl sebacate to become semisolid, whereas certain substituted aromatic ethers, although of greatly increased viscosity, were still in the liquid state at equivalent exposures. The major consideration in the use of polyphenyl ethers continues to be the difficulty of preparation and purification of such compounds.

This report is to be printed as Wright Air Development Center Technical Report 57-299, Part II. Copies will be sent to organizations receiving proceedings.

BMI-125A-8

Matuszak Alfred H
THE DEVELOPMENT OF NUCLEAR RADIATION RESISTANT TURBINE ENGINE LUBRICANTS,
Esso Research and Engineering Co., Products Research Div., Linden, N.J. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 26 pp. (6 refs).

This paper constitutes a progress report of work screening various materials for possible use in the development of radiation resistant lubricants for nuclear aircraft.

In Phase I of this work, finished mineral and synthetic lubricants have been screened at gamma dosages up to 10^8 roentgens. The most promising of the mineral oils tested is an inhibited paraffinic aviation-type oil. WS-3019, an experimental oil of the MIL-L-25336 type, appears to be the most stable of the finished synthetic oils.

In the work designed to develop a more radiation resistant lubricant (Phase II), potential mineral and synthetic base stocks are being screened, also at 10^8 roentgens. This screening has revealed that inhibited paraffinic base stocks are more resistant to 10^8 roentgens than the synthetics evaluated. An inhibited paraffinic base appears to be the most promising Phase II oil tested to date. Of the synthetics, tridecyl carbonate and tridecyl terephthalate appear to be the most attractive. Certain shortcomings exist in all candidates, however.

The more critical changes induced by 10^8 roentgens on the properties of the promising materials are discussed. Also general conclusions concerning the changes affected by radiation of fifty-seven materials screened in this work are summarized.

BMI-125A-9

Lusebrink T R, et al.
NUCLEAR RADIATION OF JET FUELS: EFFECT OF DOSE ON THERMAL STABILITY AND OTHER PROPERTIES,
Shell Development Co., Emeryville, Calif. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 32 pp.

The effects of radiation dose and dose rate on thermal stability and other properties have been investigated for a number of typical jet fuels. In the range of 1×10^7 to 1×10^9r some of the fuel properties, such as density, refractive index, hydrogen content and heat of combustion are linear functions of dose. The viscosity, however, increases more rapidly than dose, whereas the rate of change of parameters measuring unsaturation decreases with dosage, due to the high reactivity of the radiolysis products. On the other hand, thermal stability-log-dosage curves take a sinusoidal form, similar in shape but differing in amplitude. Low doses invariably reduce thermal stability, but irradiation to high levels can lead to marked improvement. The tremendous losses in thermal stability observed with fuels subjected to a low-intensity neutron-gamma flux can be accounted for by dosage and soluble iron effects.

Numerous tables and curves are included.

BMI-125A-10

Neely R J
VARIATION IN RESULTS OF DYNAMICALLY AND STATICALLY IRRADIATED AIRCRAFT FLUIDS,
Convair Division, Fort Worth, Tex. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 12 pp. (3 refs).

Five cases of dynamic and static irradiations of aircraft fluids are presented. The dynamic samples were irradiated while operating in component aircraft systems. The static samples were placed to receive approximately the same integrated flux dose. Static and dynamic results were divergent.

Testing of the fluids by such standard evaluation procedures as viscosity, specific gravity, index of refraction, etc., indicated that breakdown of the fluid was accelerated by operation in a nuclear environment. Predictions of the service life of these particular fluids could not be based on static irradiation. Changes generally occurred most often in the viscosity and neutralization number of the fluids.

BMI-125A-11

Droegemueller E A
DYNAMIC GAMMA RADIATION EFFECTS ON HYDROCARBON FLUIDS UNDER THERMAL, OXIDATIVE, AND MECHANICAL STRESS,
Pratt & Whitney Aircraft, East Hartford, Conn. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 39 pp.

A pair of specially designed "hot" cells with common dry storage well have been constructed to use a high specific activity source of cobalt-60, to provide a high level gamma radiation flux for dynamic tests on hydrocarbon fluids for use in future aircraft propulsion units. Standard fuel and lubricant test equipment were modified to allow the introduction of the cobalt-60 gamma source material as close as possible to the test section under thermal, oxidative, and mechanical stress so as to obtain the highest possible gamma flux.

A large number of lubricants were screened in an oil coker similar to a WADC Deposition Tester, and a group of fuels were checked in a modified CFR Fuel Coker. The effect of total accumulated radiation dose on lubricants relative to the formation of sludge, coke, and neutralization number was investigated. The effect of dynamic radiation, total accumulated dose, and preheater temperature on goodness number was shown for several fuels.

A corrosion oil coker was developed to show the effect of dynamic radiation on the corrosive properties of the lubricants while under thermal and oxidative stress. Extreme differences were found between lubricants in their attack of metal specimens.

A modified high-temperature bearing head using a 100 mm bearing was operated on an ERDCO Universal Tester while in a high gamma flux field. Sudden and dramatic changes in the physical properties of the lubricants were observed while under test.

The program described in this paper was instituted to aid Pratt and Whitney Aircraft in defining the limitations of presently available experimental hydrocarbon fluids for use in

future aircraft propulsion units. The stress of radiation was added to the thermal, oxidative, and mechanical stress to further damage the fluids in an attempt to find the most stable compounds. It was felt that the added stress of radiation would help to separate marginally stable compounds from the best available compounds.

BMI-125A-12

Wall L A, Florin R E and Brown D W
EFFECT OF IONIZING RADIATION ON FLUOROCARBONS AND RELATED SUBSTANCES, National Bureau of Standards, Washington 25, D.C. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, October 22-23, 1957, 11 pp. (11 refs).

An investigation of the radiolysis of liquid fluorocarbons and also polytetrafluoroethylene was made. It was found that the aromatic fluorocarbon, C_6F_6, is considerably more stable than the aliphatic fluorocarbon, C_7F_{16}, as measured by the acceleration of styrene polymerization in the presence of the above compounds. In the radiolysis of pure C_6F_6, as in that of C_6H_6, "polymer" formation is the most important result. Although C_6F_6 turns dark during radiolysis in glass vessels long before C_6H_6 does, the yields of products are similar in magnitude. Since glass is likely to be deleterious to fluorocarbons, future work will be conducted in nickel vessels. With polytetrafluoroethylene gaseous radiolysis products were quite low.

The degradation of fluorocarbon polymers is discussed, and it is pointed out that a fluorocarbon polymer capable of at least some crosslinking in the presence of radiation would be more resistant to radiation than a polymer incapable of crosslinking, as far as physical properties are concerned. It is also probable that the presence of aromatic fluorocarbon groups or other types of unsaturated groups in a polymer may lead to crosslinking and therefore enhance radiation resistance.

BMI-125A-13

Mahoney C L, et al.
DEVELOPMENT OF RADIATION RESISTANT HIGH TEMPERATURE LUBRICANTS, Shell Development Co., Emeryville, Calif. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 9 pp.

Conventional ester and petroleum hydrocarbon based lubricants, depending on inhibitors for resistance to oxidation, are very sensitive to radiation damage and lack sufficient stability for high temperature use. Selected aromatic compounds, designed for stability in absence of inhibitors, appear to be suitable for use at operating temperatures and radiation levels considerably higher than present oils. Stable aromatic esters, carbonates, and polyphenyl compounds have been investigated, but polyphenyl ester derivatives have shown the greatest over-all promise. Unsubstituted polyphenyl ethers and ethers substituted with α-cumyl or tert-butyl groups have good oxidation and thermal stability and undergo only moderate changes in physical properties during irradiation to 10^9 rad. The lubrication characteristics of these ethers are markedly better than those of aromatic hydrocarbons. Improvements in their low-temperature properties through structural modifications are being investigated and preliminary data are promising.

BMI-125A-14

Fainman M Z
THE BEHAVIOR OF FUELS AND LUBRICANTS IN DYNAMIC TEST EQUIPMENT OPERATING IN A RADIATION ENVIRONMENT,
Inland Testing Laboratories, Morton Grove, Ill. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 16 pp.

The chemistry laboratory and cobalt-60 radiation facility described at the first 125A Radiation Effects Symposium are now complete. The physical and chemical properties of fuels and lubricants are determined on test samples which not only allow the screening of products for use in the test machinery, but also enable interested participants to make intelligent appraisals of the types of products that will operate satisfactorily in a radiation environment. Preliminary experiments in the radiation environment, as well as the results of other investigators, indicate that the rate of oxidation of organic materials is enhanced by radiation. As a consequence, emphasis has been placed upon the operation of the CFR Fuel Coker, the Model C Panel Coker, and the Model F Deposition Tester. The accelerated damage to most materials evaluated in this test equipment justifies their use as preliminary screening devices before use in other machinery.

BNL-1584

Williams R R, Jr. and Hamill W H

CHEMICAL EFFECTS OF ELECTRON CAPTURE BY SOLUTES IN HYDROCARBONS DURING GAMMA IRRADIATION,
Brookhaven National Laboratory, Upton, N.Y., and University of Notre Dame, Notre Dame, Ind., September (1953), 7 pp. (7 refs).

The chemical effects of electron capture by solutes in hydrocarbons during gamma irradiation are presented and discussed. The experimental method is described. The results are presented in two tables: Reactions of Solutes in Hydrocarbons for Co^{60} Gamma Radiation at 25°C, and First Ionization Potentials, Electron Affinites, and Bond Dissociation Energies in ev.

CF-55-9-163

Michelson C
RADIATION DAMAGE TO FREON,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., September 30, 1955, 6 pp. (1 ref).

This study predicts the decomposition of Freon-11 by gamma radiation, resulting in the formation of ions which are incompatible with stainless steel. The possibility of a corrosion problem in the HRT cold traps and refrigeration system, and also the possibility of gas binding and heavy oil formation must therefore be considered.

CF-56-8-198

Silverman M D, et al.
RADIATION DAMAGE TO FREON,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., August 27, 1956, 4 pp. (5 refs).

Radiation damage to Freon-11 (CCl_3F) has been reported at the Army irradiation facility at Dugway Proving Ground. The radiation stability of similar organic compounds has been summarized in recent reviews by Tolbert and Lemmon and by McDonell and Newton. Accordingly, the feasibility of using Freon as a secondary refrigerant for the HRT refrigeration system was questioned and discussed in memos by Michelson and Rudolph.

Since Freon was used without difficulty for the HRE, it was originally planned to use essentially the same refrigeration system for the HRT. However, as emphasized by Michelson, the HRE ran for short periods of time and at lower intensities than those contemplated for the HRT. Hence, it was deemed advisable to conduct a radiation experiment on Freon-11 to determine the decomposition products and their amounts under conditions approximating those anticipated for the HRT.

A Van de Graaff accelerator was used for this decomposition study, as it provides a 100-fold more intense radiation source than the 1100 curie Co-60 source (Chemistry Division) which was not available for prolonged continuous exposures and which was experimentally inadequate.

CRL-PR-2

Fainman M Z, Simpson R E and Offenberg N F
EVALUATION OF FUELS, HYDRAULIC FLUIDS, AND LUBRICANTS UNDER DYNAMIC CONDITIONS IN THE PRESENCE OF GAMMA RADIATION,
Inland Testing Laboratories, Cook Electric Co., Morton Grove, Ill., Contract No. AF33(616)-3865, June 15, 1957, 51 pp.

A research program has been initiated for the evaluation of fuels, hydraulic fluids, and lubricants, in the presence as well as in the absence of gamma radiation.

A general chemistry laboratory and a cell sufficiently shielded to house a 100,000 curie Co^{60} source have been built to conduct this investigation. This research facility was designed and privately financed by the Cook Electric Company. The laboratory is now in operation to perform over 90% of the military specification tests for fuels, hydraulic fluids, and lubricants. Seven of the dynamic test machines have been received and are being calibrated and checked in. The modified deposition rig will be used for preliminary experiments in an irradiation environment during July 1957.

Two shipments of cobalt-60 totaling 22,500 curies have been received. They will be used for preliminary irradiation studies.

IDO-16441

Keller F R
GAMMA DAMAGE TO ETHYLENE GLYCOL IN MTR 90-DAY COOLED FUEL ELEMENT SHIPMENT,
Phillips Petroleum Company, MTR Operations Branch, Idaho Falls, Idaho, Contract No. AT(10-1)-205, February 20, 1958, 3 pp.

A shipment of 90-day old spent MTR fuel elements was made in late November 1957 using ethylene glycol as an antifreeze agent in the water surrounding the four elements within the shipping cask.

Radiation damage to the ethylene glycol was apparent after five days in the cask. An oil phase and an aqueous phase were present in the liquid drained from the cask, and some gelatinous material was observed on the fuel elements and the cask walls.

As a consequence of this experience, the use of ethylene glycol as an antifreeze has been discontinued in shipments of MTR fuel elements.

IEC-0658

Lucchesi P J, et al.
HIGH TEMPERATURE RADIATION CHEMISTRY OF HYDROCARBONS,
ESSO Research and Engineering Co., Linden, N. J. Paper presented in Industrial and Engineering Chemistry, Vol. 50, pp. 878-884, June (1958).

Radiation-induced cracking of pure hydrocarbons and mixtures is a long-chain reaction at 320° to 510°C. Product distributions are similar to those obtained with thermal cracking. The radiation yields (10^4 to 10^5) increase with increasing temperature, are lower in the liquid than the vapor phase, and increase at lower intensity. Radiocracking results from both cobalt-60 and pile work can be qualitatively explained by assuming the Rice-Herzfeld radical mechanism. Close agreement between calculated and predicted radiation yields indicates that atmospheric pressure radiocracking is an ordinary radical chain reaction. This gives new insight into the mechanism of thermal decomposition of hydrocarbons, which is believed to be a chain process of low chain length.

LAC-NR-51 (Vol. 5)-50

Fainman M Z
THE BEHAVIOR OF FUELS AND LUBRICANTS IN DYNAMIC TEST EQUIPMENT OPERATING IN THE PRESENCE OF GAMMA RADIATION,
Inland Testing Laboratories, Morton Grove, Ill. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 12 pp. (1 ref).

Seventy-nine fuels and forty-one lubricants were studied to determine their suitability for use in a nuclear-powered aircraft. The materials were evaluated in dynamic test equipment operating in a gamma-radiation environment provided by 50,000 curies of cobalt-60. The mechanical test machines used were those that have been useful in predicting the performance of fuels and lubricants in the aircraft gas turbine. These mechanical tests conducted at elevated temperatures in a radiation environment often affect materials more drastically and at lower doses of radiation than anticipated, indicating that it is necessary to assess the effects of mechanical, thermal, and radiation stresses as a combined environment. Ten fuels and six lubricants were chosen which showed the best performance. Sufficient data were accumulated to show that a number of these products will operate satisfactorily at radiation doses of at least 10^{10} ergs/gram carbon. These materials are suggested as the most satisfactory of those evaluated for use in a nuclear-propelled aircraft.

LAC-NR-51 (Vol. 5)-51

Rice W L R and Cox W L, Lt. (USAF)
THE DEVELOPMENT OF NUCLEAR RADIATION RESISTANT SOLID FILM LUBRICANTS,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corporation, Marietta, Georgia, 42 pp. (11 refs).

The effect of radiation on solid film lubricants is discussed. Data on wear life, corrosion resistance, fluid resistance, and thermal stability are reported for twelve films. Exposures were conducted in the presence of both gamma and neutron irradiations. In general, little change was noted in the film performance indicating stability of the films.

LAC-NR-51 (Vol. 5)-52

Haley F A
INTEREFFECTS BETWEEN REACTOR RADIATION AND MIL-L-7808C AIRCRAFT TURBINE OIL,
Convair, Div. of General Dynamics Corp., Fort Worth, Tex. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corporation, Marietta, Ga., 12 pp. (1 ref).

In an experiment to investigate the intereffects of oil and reactor radiation, six specimens of MIL-L-7808C aircraft turbine oil were irradiated in the form of slabs of one-half inch thickness. The specimens were stacked so that each acted to shield those behind it and the neutron and gamma radiation was measured between specimens.

Comparison of measured values with theoretical curves for the charge in the radiation field as it progressed through the oil shows that the attenuation of neutrons and gammas through oil can be predicted with reasonable accuracy.

Although the doses received by the specimens were not sufficient to cause extensive degradation of properties, some increases in viscosity and neutralization number were noted, the extent of change in the oil nearer the reactor being greater than in the more remote specimens.

LAC-NR-51 (Vol. 5)-53

Mahoney C L, et al.
DEVELOPMENT OF RADIATION-RESISTANT HIGH-TEMPERATURE LUBRICANTS,
Shell Development Co., Emeryville, Calif. Paper presented at the 3rd Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga. 7 pp.

Polyphenyl ethers are very promising materials for further development as radiation-resistant high-temperature lubricants. The unsubstituted polyphenyl ethers are far more stable than presently-used lubricants and can be classed with the most resistant types of aromatic compounds (polyphenyls, aromatic silanes, etc.) with respect to radiation, oxidation and thermal stability. Furthermore, these ethers have much lower melting points, better physical properties and much better lubrication characteristics than the other aromatic materials. Liquid unsubstituted ethers having pour points of 5° and 40°F have been prepared. Initial thermal decomposition temperatures of these ethers are 830°F or higher.

Selected alkyl-substituted polyphenyl ethers, α-cumyl and tert-butyl derivatives, although less stable than the unsubstituted compounds are much more resistant to radiation, oxidation and thermal decomposition than typical antioxidant-containing oils.

Practical methods of preparing liquid polyphenyl ethers are being actively investigated with real promise of success.

LE-0758-1

Handschy J R A, Armstrong J W and Gordon B E
GREASES STABLE TO RADIATION UNDER DYNAMIC CONDITIONS,
Lubricating Engineering, Vol. 14, No. 7, pp. 292-297, July (1958), (8 refs).

Conventional greases exhibit marked changes in physical properties upon exposure to large doses of high-energy radiation. Heretofore, these changes have been evaluated in the usual bench-scale tests after irradiating the greases in vials under static conditions. While this method is quite effective in identifying and eliminating those products most susceptible to radiation damage, it yields little information on the progressive degradation of greases under the combined effects of simultaneous irradiation, oxidation, and mechanical working typical of actual service. To overcome this limitation, a modification of the Shell Roll Tester suitable for underwater operating has been developed and installed in the Gamma Facility pool at the Materials Testing Reactor, Idaho Falls, Idaho. Details of this test rig are presented in the text. The equipment permits periodic examination of the degradation in mechanical stability of grease under dynamic irradiation conditions. Mechanical stability has been found to be the parameter most sensitive to radiation.

The screening of many greases and grease components under both static and dynamic conditions has indicated the thickeners and oils which show the greatest resistance to radiation degradation. Greases prepared with these components retain a good measure of their initial serviceability even after exposure to more than 5×10^8 roentgens.

N-1058-3

Rice William L R
EFFECTS OF GAMMA RADIATION ON ORGANIC FLUIDS AND LUBRICANTS,
Nucleonics, Vol. 16, No. 10, pp. 101-103, October (1958).

Irradiations of static samples of lubricants and other organic materials, were conducted at ambient temperatures in the spent-fuel-element canal of the Materials Testing Reactor and at Hanford. Dosages from the two sources are reported in roentgens, but, in accordance with standard Air Force practice, the roentgen values were converted to the carbon standard (87.1 ergs per gram of carbon per roentgen). Dosages are not corrected for gamma attenuation.

The following fluids were irradiated and tested: (a) a refined petroleum oil such as is used in aircraft reciprocating (piston) engines; (b) a diester-based aircraft-instrument lubricating oil; (c) a polymer-thickened silicate ester high-temperature hydraulic fluid; (d) an alkyl aromatic fluid, monoisopropylbiphenyl (MIPB); (e) a paraffinic kerosene (special JP-5 from Eastern United States crude).

NAA-SR-1288

Colichman E L and Gercke R H
RADIATION STABILITY OF THE TERPHENYLS AND OTHER POLYPHENYL MATERIALS AS MEASURED BY GAS EVOLUTION,
Nuclear Engineering and Manufacturing, North American Aviation, Inc., Downey, Calif., Contract No. AT(11-1)-Gen-8, June 15, 1955, 23 pp. (13 refs).

The gas yield resulting from the action of 1.0-Mev electrons on polyphenyls was used to measure the radiation stability (expressed as G_{Gas}) of some particularly promising polyphenyl organics for use as reactor coolants and/or moderators. The materials studied were pure ortho-, meta-, and para-terphenyl, biphenyl, and para-quaterphenyl as well as the mixtures para-terphenyl--meta-terphenyl and para-quaterphenyl--meta-terphenyl. Irradiations were carried out over the range 30° to 350°C.

Para-terphenyl was found to be considerably more stable than ortho-, and meta-terphenyl, these being approximately equal. Para-quaterphenyl is slightly more stable than para-terphenyl, biphenyl (at 30°C) being equal in stability to ortho- and meta-terphenyl. The stability of both mixtures studied was closer to that of the more stable component than expected, a synergistic effect on the stability being noted. The radiation stability of all the polyphenyls studied increases with "polymer" concentration. This result and the enhanced stability of the mixtures are explained on the basis of a proposed fluorescence-protective mechanism.

NARF-57-19T (Vol. 4)-2 X-21783

Kinderman E M, et al.
THE EFFECTS OF HIGH-ENERGY, HIGH-INTENSITY RADIATION ON ORGANIC FLUIDS, Stanford Research Institute, Menlo Park, Calif. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, May 22-23, 1957, Convair, Fort Worth, Tex., 16 pp.

An investigation of the effects of molecular structure and type of radiation (electron and gamma) on the radiolysis of organic liquids has been completed. Data are presented for comparison of both effects. Aliphatic and alkyl aromatic hydrocarbons and esters were studied. Yields of radiolysis products were determined by a variety of analytical techniques, the principle ones being mass spectrometry and gas partition chromatography.

The observed radiation stability of the compounds varied in a systematic manner. The principle radiolysis products formed were those predictable from mass spectrometry and chemical data. Qualitative similarities in product were found in the irradiations with electrons and gamma rays.

NARF-58-39T MR-N-218

Minden B M
THE EFFECT OF NUCLEAR RADIATION ON PROTECTIVE COATINGS, Convair, Div. of General Dynamics Corp., Fort Worth, Tex., Contract No. AT-33(600)-32054, September 12, 1958, 34 pp. (10 refs).

Dow No. 17 anodic coating for magnesium and Hardas (sulfuric acid) anodic coating for aluminum alloys were irradiated for 40 hours at 500 kw [6.5×10^{14} n/cm^2, E>2.9 Mev, and 8.1×10^9 ergs/g(C)]. Post-exposure salt-spray tests resulted in excessive corrosion on the 24S aluminum alloy and no damage to magnesium-thorium alloy.

General Paint Corporation Epoxy Primer HX-10447 was irradiated for 20 hours at 500 kw at 300°F [3.2×10^{14} n/cm^2, E > 2.9 Mev, and 4.1×10^9 ergs/g(C)]. The Epoxy resin primer system showed very good radiation resistance.

NP-5981

McEwen Malcolm
PRELIMINARY ENGINEERING STUDY OF ORGANIC NUCLEAR REACTOR COOLANT-MODERATORS,
Monsanto Chemical Co., Research and Engineering Div., Dayton, Ohio, Contract No. NObs-66067, March 31, 1956, 80 pp.

A test loop was designed, constructed, and installed in the Brookhaven National Laboratory reactor. It was operated for the purpose of making a preliminary engineering study of the feasibility of using organic materials as nuclear reactor coolant-moderators.

Even though the range of conditions obtainable in this loop system did not (and could not) cover all conditions that would exist in reactors, the data are sufficiently detailed on diphenyl and monoisopropylbiphenyl to allow reasonably safe extrapolations to more stringent conditions.

NP-6431

EFFECTS OF RADIATION ON AIRCRAFT LUBRICANTS AND FUELS,
Quarterly Report No. 6, California Research Corp., Richmond, Calif., Contract No. AF33(616)-3184, May 31, 1957, 186 pp. (14 refs).

A special section entitled "Lubricant Product Summary" begins on page iv. All data are tabulated for the current best products developed in this research on greases, hydraulic fluids, gas turbine oils, and gear lubricants.

Exploratory synthesis in support of the lubricant development emphasized diarylalkanes. These materials were attractive as base stocks because of good physical properties. Of three different 1, 9-bis(butylphenyl)-nonanes prepared (200-gram batches), the n-alkyl derivative had the best viscosity and pour point properties. However, infrared spectra showed carbonyl groups which possibly caused observed oxidation. Several alkyl diphenyl ethers were also synthesized during this period, as well as alkylbenzenes and aryl esters.

Five pounds of the preferred radiation resistant grease, Calresearch 159 (alkylbiphenylsodium terephthalamate), was irradiated for 8×10^8 r to provide sample for test work. Radiation damage was moderate; complete tests are in progress. Several other greases of the terephthalamate type were irradiated for 10^9 r at 350°F. Damage to physical properties was not severe; functional test work is progressing. In exploratory research a grease made from an alkylbiphenyl fluid and a sodium mixed benzoate and N-octadecylterephthalamate gelling agent was attractive in preliminary oxidation and radiation stability tests. Different antioxidants are under study in this grease. Evaporation tests at 350°F on new oils showed a trioctyl-diphenyl ether and a polyoctyl-m-terphenyl to be attractive as base fluids for the further grease formulations.

In a further search for new bases for hydraulic fluids, an experimental Dow Corning silicone having a high phenyl content was found to survive 10^9 r. This unusual performance was confirmed by a low gas evolution for this dosage: about 2.4 ml per gram.

CFR fuel coking tests were performed on the five JP-4 fuels irradiated for gamma dosages from 1 to 10×10^8 r. Thermal stability of all five fuels was better after 10^9 r

than on the original. At 5 x 10^8 r, four out of five fuels were better than original, while at 10^8 r only two were better. These data suggest the need for further test work on samples irradiated below the 10^8 r level.

NYO-3313

Hayward James C, Jr.
POLYMERIZATION OF ETHYLENE INITIATED BY GAMMA RADIATION (THESIS), Yale University, New Haven, Conn., Contract No. AT(30-1)-1173, June (1955), 268 pp. (129 refs).

Initial rates of the polymerization of ethylene initiated by gamma radiation have been derived from total pressure measurements on batch systems of ethylene. Initial rates between about 0.1 and 60% per day were obtained at temperatures between 80° and 460°F, pressures between 1/2 and 21 atm, and a radiation intensity of the order of 100,000 r/hr. The initial rates correspond to ion-pair yields between 5 and 2,500 and to G values between 20 and 10,000. The product was generally a liquid; however, a white waxy solid was obtained at room temperature and the higher pressures. The reaction is homogeneous and is strongly inhibited by a trace concentration of oxygen. Furthermore, the effect of a saturation electric field on the rate of polymerization at 80°F and 2 atm is small, if not completely negligible.

A simplified version of a free-radical polymerization mechanism is presented. According to this mechanism, the ion-neutralization energy is ineffective in the initiation of ethylene polymerization and, furthermore, the chain-transfer process by which the liquid product is formed at elevated temperatures is suppressed by an increase in pressure.

REIC-4(Add 1) AD-210760

Cosgrove S L
THE EFFECT OF NUCLEAR RADIATION ON LUBRICANTS AND HYDRAULIC FLUIDS, The Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio, March 31, 1959, 26 pp. (42 refs).

This report is an addendum to REIC Report No. 4, "The Effect of Nuclear Radiation on Lubricants and Hydraulic Fluids." It reviews publications, reports and other communications received by the Radiation Effects Information Center during 1958.

Those basic radiation studies on organic compounds of significance to lubricant and hydraulic fluid development are reviewed, and their significance is discussed.

Radiation-resistant gas-turbine-lubricant development during the past year has centered around the expanded study of polyphenyl ethers and alkylated aromatic ethers. Meta-linked polyphenyl ethers (unhibited) show promise for use in the 0 to 700°F range and at exposures up to 1 x 10^{11} ergs g^{-1} (C). Alkylated aromatic ethers (containing anti-oxidants) are somewhat less radiation stable, but show a useful temperature range of approximately -35° to 600°F.

Alkylated diphenyl ethers and diaryl alkanes show the most promise for use in conventional hydraulic systems under irradiation conditions. In hydraulic systems which would tolerate high pour points (about 5°F) and marginal high-temperature viscosity, unsubstituted polyphenyl ethers could be used to advantage.

The combination of radiation-stable fluids and modified soap (terephthalamates) or non-soap thickeners has resulted in greases of adequate radiation stability for anticipated ANP needs. Likewise, commercially available dry-film lubricants show adequate radiation stability for anticipated ANP applications.

REIC-4 AD-154432

Cosgrove S L
THE EFFECT OF NUCLEAR RADIATION ON LUBRICANTS AND HYDRAULIC FLUIDS,
Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio, Contract No. AF33(616)-5171, April 30, 1958, 70 pp. (50 refs).

This report presents the state of the art of the effect of nuclear radiation on aircraft fluids from 1955 through 1957.

A brief review of the mechanism by which organic materials degrade chemically under the influence of nuclear radiation is followed by a discussion of the radiation stability of current aircraft lubricants and hydraulic fluids. In general, military-specification aircraft lubricants and hydraulic fluids show inadequate radiation stability for projected ANP purposes. The incorporation of antirads into these materials does not provide the necessary additional stability.

Aromatic compounds, specifically alkyl biphenyls, and substituted aromatic ethers show the most promise as radiation-resistant base stocks. In most cases their performance properties have yet to be fully evaluated, especially under in-source, or dynamic irradiation conditions.

Lubricants are categorized by function; radiation-resistant lubricant and hydraulic-fluid development programs are reviewed by chemical species rather than by the contracting agency responsible for their development. The appendixes contain selected tabular data showing the effects of radiation on both conventional materials and those developed for projected ANP use.

REIC-TM-11

Hillenbrand L J
THE EFFECT OF NUCLEAR RADIATION ON HYDROCARBON FUELS,
The Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio, Contract No. AF33(616)-5171, November 30, 1958, 11 pp. (5 refs).

It is not surprising to find that complex mixtures such as jet fuels respond to irradiation in diverse ways. It is satisfying, however, to find that, in a qualitative sense, the overall picture of the effects of radiation upon hydrocarbon jet fuels is also quite consistent.

The extent to which various radiation doses will affect the usual physical and chemical properties of fuels has been measured. No simple relationship seems to exist between the effects of irradiation upon thermal stability and upon other fuel properties. However, both the thermal-stability tests and the fuel-property determinations indicate that dehydrogenation, polymerization, and degradation occur. It is interesting to note, furthermore, that the changes in thermal stability caused by irradiation (as measured in a fuel coker) tend to disappear after several months of storage.

REIC-TM-13

Wyant Robert E
THE EFFECT OF NUCLEAR RADIATION ON ORGANIC HEAT-TRANSFER MATERIALS, REIC, Battelle Memorial Institute, Columbus 1, Ohio, February 28, 1959, 16 pp. (39 refs).

This memorandum summarizes the information available at the Radiation Effects Information Center on the radiation stability of organic heat-transfer materials.

Of the materials surveyed, the terphenyls show the greatest radiation resistance and are the preferred class of organic heat-transfer materials for high radiation exposures. At low exposures, the para-isomer shows the greatest resistance, while at higher exposures the three isomers approach one another in stability. Monoisopropylbiphenyl, biphenyl, diphenyl ether, and silicate esters also appear to possess good radiation stability.

Ethylene glycol, chlorinated diphenyls, DC-710 silicone, and phosphate esters have poor stability and should probably not be used where total exposure exceeds about 8.5×10^9 ergs g^{-1} (C).

S-13711 NP-6256

Minor H B, et al.
RESEARCH ON DETERMINATION OF THE STABILITY OF JET ENGINE FUELS, Quarterly Progress Report No. 1, September 1 thru November 30, 1956, Shell Development Co., Emeryville, California, Contract No. AF33(616)-3888 (1956), 33 pp.

The possibility that the radiation resistance of a jet fuel can be enhanced by the addition of aromatic compounds as "protectors" is being examined. It has been found that such compounds, contrary to their behavior in the free state, are quite reactive in jet fuels on exposure to 10^8 r, although the products are not necessarily harmful. The extent of reaction is greatest at low initial concentration and varies greatly with both the nature of the aromatic and the substrate. Thus the order of decreasing reactivity is anthracene, hetero aromatics, naphthalene, phenanthrene and diphenyl. Reactivities are lower in aromatic substrates. The reaction appears to involve radical scavenging, leading (probably) to alkylated aromatics.

The changes in composition occurring in both jet fuel and model compounds are very complex and model systems are being used to simplify the unravelling of the reaction mechanism. Even with systems such as cyclohexane and decalin, however, many new molecular species are formed, involving dehydrogenation, ring scission, demethylation, polymerization and (with decalin) cis-transisomerization. The effect of radiation atmosphere is not marked.

Oxidation in storage of six CRC jet fuels resulted in considerable variations in subsequent high temperature stability tests. Of six fuels, two exhibited pronounced improvement in thermal stability, three were degraded by aging and one was substantially unchanged. Evaluation of a number of promising additives for the preservation of both storage and thermal stability is continuing. A few inhibitors initially improve thermal stability but their effect is less than that obtained from dispersants.

An ozone-containing atmosphere had no adverse effect on the thermal stability of a SR JP-4. In fact, one test showed that the mild oxidation which occurred with ozone somewhat extended the plugging time of the fuel.

Trace metal analyses by neutron activation at Oak Ridge National Laboratory confirmed earlier data on soluble copper and revealed the presence of nickel and, possible, vanadium in jet fuels. Analyses for iron, chromium and cobalt were unsuccessful.

S-13721

Minor Harry B, et al.
RESEARCH ON DETERMINATION OF THE STABILITY OF JET ENGINE FUELS, Quarterly Progress Report No. 2, December 1, 1956 through February 28, 1957, Shell Development Co., Emeryville, Calif., Contract No. AF33(616)-3888, (1957), 27 pp.

Examination of three jet fuels exposed to mixed gamma-neutron irradiation in the SPT No. 2 Test at Convair shows that the thermal stability of all three fuels was considerably decreased by the exposure in spite of the fact that little chemical damage occurred. These results are considerably different than those observed after exposure to 10^8 gamma from spent fuel elements in which two of the three fuels were improved in thermal stability and the third suffered only a relatively slight decrease, even though chemical attack was considerable. The cause of the behavior following the neutron exposure is not known, although it may be connected with the formation of peroxides which resulted as a consequence of the exposure. The investigation of the radiation stabilities of fuel components and model compounds has been continued with the object of identifying the types of compounds that lead to poor radiation stability.

At the present time we would conclude that the best choice of an ANP chemical fuel would be one composed almost exclusively of naphthenes. Prior to the results of the SPT tests, our recommendations would probably have included fuels which also contained paraffinic components. However, this is extremely tentative and additional information on the effect of neutron irradiation on thermal stability must be obtained.

S-13724 NP-6357

Mahoney C L, et al.
ENGINE OIL DEVELOPMENT FOR WRIGHT AIR DEVELOPMENT CENTER, Quarterly Progress Report No. 6, February 1 through April 30, 1957, Shell Development Co., Emeryville, Calif., Contract No. AF33(616)-3182, (1957), 27 pp.

The investigation of polyphenyl ether derivatives for use as radiation-resistant high-temperature lubricants has continued to show promise. In general, polyphenyl ethers have good radiation resistance and thermal stability though a few derivatives are deficient in this latter respect. Lubrication characteristics, as measured by high temperature four-ball wear tests, are also good for nearly all of these compounds. For ethers as well as most other potential high-temperature lubricants, upper useful temperature limits are much more often set by oxidation stability than by the other properties discussed above. Unsubstituted polyphenyl ethers are appreciably more resistant to oxidation and thermal decomposition than are derivatives containing alkyl substituents. Unsubstituted ethers that are readily prepared, however, have rather high melting points. The most promising substituted ethers examined so far contain tert-butyl or α-cumyl groups. With these substituents, low-melting compounds can be prepared which undergo little change in oxidation-corrosion tests at temperatures approaching 500°F and form little coke at 800°F panel temperatures. Various stability and physical property relationships have been developed for polyphenyl ether derivatives. Only the structure and the molecular weight need be known to make a close prediction of the high temperature performance limits and physical properties.

SCTM 139-59(16)

Cropper W H
THE RADIATION CHEMISTRY OF ORGANIC DYES,
Sandia Corporation, Albuquerque, New Mexico, July 29, 1959, 32 pp. (37 refs).

The general features of the solution radiation chemistry of dyes are considered in a review of the important work in this field.

For methylene blue, the dependence of the decolorization yield on the following is discussed:

a. The presence or absence of dissolved oxygen,

b. The presence of organic and inorganic added solutes,

c. The presence of impurities,

d. Changes in energy and dose rate of the radiation, and

e. Changes in pH.

Also for methylene blue, the equations developed in an earlier work by the author are applied to many of the above situations. The radiation chemistry of numerous other dyes is also considered.

A section is included which develops a viewpoint concerning the oxidizing and reducing power of radicals in solution, based on the calculation of oxidation potentials, and applications are made to organic dye systems. Remarks are also made concerning the effect of pH and nonaqueous solvents on the mechanisms involved in the radiation decomposition of dyes.

SLA-Tr-R-2164

Shekhtman I L, Krasnovskii A A and Vereschinskii I V
A STUDY OF THE DECOLORATION OF METHYLENE BLUE UNDER THE INFLUENCE OF ROENTGEN RAYS,
Translated from Dokladi Akademii Nauk SSSR, Reports of the Academy of Science, USSR, Vol. LXXIV, No. 4, pp. 767-769, (1950), (4 refs).

The decoloration of an aqueous solution of methylene blue under the influence of roentgen rays was investigated. This investigation was for the purpose of studying the regularities which are connected with the mechanism of the action of radiation on aqueous solutions of organic substances.

The method of exposure is discussed. The method of determining the total dose on the surface of a compound is presented. The results of the experiment are presented in four curves.

Also investigated is the influence of the addition of quinone, hydroquinone, glucose, and glycerine to the solution. The obtained results show that the addition to the dye solution of foreign organic compounds renders a considerable blocking action.

The satisfactory reproducibility of the decoloration reaction and its adequate sensitivity to doses from 1-2 to 15-25 kiloroentgen units permits it to be applied to a series of cases as a "roentgen-chemical dosimeter."

TID-5280(Suppl. 1)-9

Sullivan L O
PROBLEMS AND COSTS ENCOUNTERED IN THE HANDLING OF IRRADIATED FUELS,
Knolls Atomic Power Laboratory, Schenectady, N.Y. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, held in Washington, D.C., September 29 and 30, 1955, 17 pp.

Operating experience in the Radioactive Materials Laboratory is described with emphasis on problems and costs encountered in the handling of irradiated fuels. The specific problems covered include control of design of the experiment, contamination, spent fuel storage, and waste disposal.

UCRL-3317

Newton Amos S and McDonell W R
THE RADIOLYSIS PRODUCTS FROM ETHYL ALCOHOL; EFFECT OF TOTAL ENERGY INPUT ON THE RADIOLYSIS PRODUCTS,
University of California Radiation Laboratory, Berkeley, Calif., Contract No. W-(7405)-Eng-48, February 28, 1956, 9 pp. (11 refs).

Data are presented on the effect of increasing bombardment on the yields of some products formed in the helium ion irradiation of liquid ethyl alcohol. The energy input was varied from 0.029 to 2.7 x 10^{22} ev/ml. Hydrogen, total carbonyl products, and vicinal glycols decrease markedly with increasing bombardment. The addition of acetaldehyde or hexene-1 causes a marked decrease in the yield of hydrogen but smaller changes in other products. The results are discussed in terms of mechanisms involving charge or excitation exchange and radical traps.

UCRL-3422

Griffith Laddie Ray
RADIATION-INDUCED REACTIONS IN NONAQUEOUS SOLUTIONS,
University of California Radiation Laboratory, Berkeley, Calif., Contract No. W-(7405)-Eng-48, July (1956), 82 pp. (38 refs).

The photoinduced disappearance of 1, 1-diphenyl-2-picryl-hydrazyl, DPPH, in solution in several organic liquids was studied.

Solutions of DPPH in cyclohexane, benzene, toluene, chlorobenzene and bromobenzene were irradiated with ultraviolet light of wave length 3126 to 3130 A. The initial rates of the disappearance of DPPH were studied spectrophotometrically and were found to be nearly independent of the amount of light absorbed by DPPH except for DPPH in cyclohexane. The rates were, however, proportional to the amount of light absorbed by the solvent.

The results indicate that the reaction is one of short-lived excited species of the solvent molecules in benzene, toluene, chlorobenzene, and bromobenzene. Furthermore, the excited species responsible for the reaction is the lowest triplet state of the solvent molecule. A reaction of free radicals produced by the photodissociation of bromobenzene probably contributes to the rate of disappearance of DPPH in bromobenzene.

Reactions of excited singlet states would not be observed in the DPPH concentration range studied because the lifetimes of the excited singlet states of these molecules are short compared with the time between collisions of these excited states with DPPH.

Investigators using the rate of disappearance of DPPH as a free-radical counting technique in radiation chemistry must consider that DPPH also reacts with at least some of the excited species present in the irradiated solutions.

WADC-TR-53-63(Pt. V) AD-118230

Nixon Alan C and Thorpe Roy E
STABILITY OF JET TURBINE FUELS, PART V,
Effects of Nuclear Radiation, Emeryville Research Center, Shell Development Co.,
Contract No. AF33(616)-2707, April (1957), 71 pp.

The Emeryville Research Center of Shell Development Company is studying the effects of ionizing radiation on jet fuels and their components, particularly with respect to radiation-induced changes in thermal stability. This investigation is progressing in three directions:

1. Evaluation of radiation damage in terms of thermal and oxidative stability.
2. Determination of the chemical changes by spectroscopy and physical separations.
3. Evaluation of the feasibility of "radiation protectors" (e.g., aromatic compounds).

Differences are noted between the damage suffered by various jet fuels, both with regard to chemical changes and stability effects. On the basis of the infrared spectra of the irradiated fuels, three general radiation reactions occur in jet fuels:

1. Formation of carbonyl compounds (in air),
2. Formation of olefine (in both air and nitrogen),
3. Destruction of benzene and naphthalene (particularly in nitrogen).

Irradiation of jet fuels to 1×10^8 roentgens increases soluble gum (as measured by chromatogum, with and without prior aging) to about the same level in either air or nitrogen. The insoluble gum level is not altered appreciably in either case.

Of the three typical jet fuels, two (a special kerosene and a JP-5 fuel - Los Angeles Basin crude) improved in thermal stability at $450^{\circ}F$ as a result of irradiation in air to 10^8 roentgens. A JP-4 fuel - San Joaquin crude - on the other hand, was affected adversely, as judged by filter-plugging tendencies. Filter-plugging time was reduced by a factor of 2 to 3. A start was made towards relating the thermal stability of these fuels to composition changes.

The results of initial studies of "radiation protectors" indicate that the aromatic compounds investigated thus far do not generally extend sponge-type protection to jet fuels; instead they themselves react in substantial amounts on irradiating, in nitrogen or air, jet fuels containing 2.5 to 20% w of added aromatic compounds.

At the present time the best choice for a radiation-stable jet fuel would appear to be one similar to the special kerosene, RAF-99, referred to above.

WADC-TR-53-83(Pt. 4) AD-97313

Swakon Edward A
DEVELOPMENT AND EVALUATION OF HIGH TEMPERATURE GREASE,
Standard Oil Co. (Indiana), Research Dept., Whiting, Ind., Contract No. AF33(038)-23687, September (1956), 54 pp.

In the work directed toward the development of an aircraft grease suitable for use over the temperature range from -65° to 450°F and higher, emphasis was placed on the development and evaluation of arylurea greases made with the best available fluids and the development of thickeners for use as high as 700°F. The chief criteria of laboratory evaluation were performance in the ABEC-NLGI Bearing Tester, the Navy Gear-Wear Tester, low-temperature torque test, apparent viscosity and linear screw-and-nut actuator.

The grease selected to replace MLG-9305 consists of DC-550 Silicone Fluid thickened with para-tolyl and para-chlorophenylurea derivatives of bitolylenediisocyanate. It was designated MLG-9349. All the thickener ingredients are commercially available and the manufacturing procedure was greatly simplified by this choice of ingredients. The corresponding grease made with DC-XF-258 Silicone Fluid was designated MLG-9360 and comes closest to meeting the proposed requirements for a grease for the temperature range from -65° to 450°F. Arylurea grease of Hercoflex 600 (polyester) is the best choice for a grease for use from -65° to 350°F with good lubricity; bearing performance at 350°F averaged about eight times longer than that obtained with MIL-G-3278 greases. Pteridine derivatives were the most promising compounds uncovered during this period for thickeners for use in greases in excess of 450°F and as high as 700°F. An anti-oxidant, MLO-55-535, was at least as good as phenothiazine or dilauryl selenide in ester greases. An antiwear agent, MLO-55-499, in silicone greases was effective in reducing wear in the Navy gear-wear test, but not enough to pass the requirements under the ten-pound-load conditions. The fluid continues to be the limiting component in the development of a grease with good lubricity for the temperature range from -65° to 450°F and above.

WADC-TR-53-337 (Pt. 3)

Raley C F
POLYNUCLEAR AROMATIC COMPOUNDS FOR HIGH TEMPERATURE LUBRICANTS,
Technical Report No. 13, Final Report for period from November 20, 1954 to November 20, 1955, Dept. of Chemistry and Chemical Engineering, Southwest Research Institute, San Antonio, Tex., Contract No. AF33(616)-276, February (1956), 45 pp. (1 ref).

The program of investigation of the class of aryl phosphate esters was continued. These materials possessed the most promising high-temperature properties of those examined. The aryl groups found to be the most thermally stable were phenyl, fluoro- and chlorophenyl, m-trifluoromethylphenyl, 4-biphenyl, dimethylphenyl, 5-indanyl and naphthyl. The simple phosphate structure was found to be quite stable. Pyrosphosphates had the drawbacks of mediocre thermal and hydrolytic stability, although apparently possessing good oxidative stability.

Compositions prepared by reacting two or three different phenols with the proper amount of $POCl_3$ were also investigated. These compositions exhibited markedly lessened tendency to crystallization. Many of the compositions possessed properties almost identical to pure compounds having equivalent phenol proportions, and had the advantage of greater ease of preparation.

A total of nine fluids were prepared which possessed a liquid range of at least -20° to 800°F. Many of the compounds and compositions prepared, including others not meeting this liquid range, are considered to have potential use value.

Several generalizations were drawn from the results of the over-all program. It was found that thermal and oxidative stability do not necessarily go together. Strongly polar substituents on the aromatic ring adversely affect hydrolytic stability. Two or more polar groups on a monocyclic ring adversely affect the thermal stability; one polar group on a bicyclic ring adversely affects thermal stability. A marked effect on such physical properties as boiling point, melting point, viscosity, etc., is observed, depending on the nature of the substituent groups. The more compact molecules generally have the greatest tendency to crystallize, with the boiling point increasing with the molecular weight.

Indications were obtained of the possibility of inhibiting the oxidation of aryl phosphates by the addition of small amounts of heterocyclic phosphates.

WADC-TR-56-207

Schmidt J E, Krimmel John A and Hobaugh John R
DEVELOPMENT OF CHAIN-TYPE POLYPHENYL COMPOUNDS FOR USE AS HIGH TEMPERATURE LUBRICANTS AND HYDRAULIC FLUIDS,
Denver Research Institute, Denver, Colo., Contract No. AF33(616)-2939, March (1956), 106 pp. (2 refs).

A comprehensive literature survey on biphenyl and other "chain type" polyphenyl compounds was conducted, and abstracted data were stored in a central card file and on IBM punch cards. Based on the collected data and correlations thereof, a series of biphenyl and terphenyl compounds were synthesized and tested for thermal stability and other physical properties.

Alkyl derivatives of biphenyl and of m-terphenyl showed considerable thermal stability. It is suggested that, among other alkyl-m-terphenyl derivatives, compounds with good thermal stability and wide liquid range may be expected.

WADC-TR-56-430 AD-110644

Rice William L R, 1/Lt. (USAF)
THE EFFECTS OF NUCLEAR RADIATION ON MILITARY SPECIFICATION GREASES,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December (1956), 23 pp. (8 refs).

A portion of the Air Force effort toward the development of nuclear radiation resistant lubricants is devoted to an evaluation of the effects of gamma radiation on available specification and nonspecification greases. Data are presented on the effects of gamma radiation on 47 greases. Many of the greases tested appear to be satisfactory for use after exposure to about 1×10^8 roentgens, the screening dosage used for these studies.

WADC-TR-57-141 AD-130857

Zebroski Edwin L and Kinderman Edwin M
A COMPARISON OF HIGH-ENERGY ELECTRON AND GAMMA IRRADIATION EFFECTS ON ORGANIC LIQUIDS,
Stanford Research Institute, for Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, Contract No. AF33(616)-3738, June (1957), 16 pp. (22 refs).

Gamma and neutron radiations are among the environmental conditions that will be encountered on nuclear-powered aircraft. It is desirable to determine the useful life of all materials, components, and systems under the anticipated conditions before actual flight testing. Screening, development, and proof-testing of materials and components to find those which will withstand these conditions of radiation require extensive and costly testing programs. Often, accelerated tests are desired in screening and "state of the art" experimental work. Accelerated testing in a gamma radiation environment can be accomplished in part by utilization of high-intensity gamma sources. Currently, such sources are limited to average dose rates of about 5×10^6 ergs/gram/hour (that is, about 5 megarep/hour). Wherever radiation exposures over 10^{11} ergs/gram are required, the irradiation times required are often too long for convenience in screening tests. It has been proposed, therefore, that high-energy electron irradiation be substituted, where applicable, for gamma irradiation to accelerate testing programs.

Present electron accelerators are capable of delivering radiation dose rates up to about 300 times greater than the best gamma sources. By shortening the test, or experiment, this greater dose rate may produce a substantial increase in the rate of learning for a given time and effort. However, before taking advantage of such rapid irradiations it must be determined if the effects of electron irradiation are equivalent to those produced by gamma irradiation.

This report presents an intercomparison of gamma and appropriate high-energy electron irradiations. Neutron irradiation is not treated here, although some of the considerations may also apply to the effects of neutron irradiation. Included in the presentation is a review of the qualitative aspects of the current theories of radiation effects, a survey of the experimental observations reported in the literature, and a summary of the recent experimental comparisons made at Stanford Research Institute.

WADC-TR-57-177

Mahoney C Lynn, et al.
ENGINE OIL DEVELOPMENT,
Shell Development Co., Emeryville, Calif., Contract No. AF33(616)-3182, November (1956), 96 pp.

Inhibited lubricants, made from ester or aliphatic-hydrocarbon base oils, are highly sensitive to radiation damage even in absence of oxygen. The effect on the base oil itself, measured by such properties as viscosity change or formation of acidic products, is generally relatively small at radiation doses less than 10^8 reps. The antioxidant, however, acts as a radical scavenger. While protecting the base oil against radiation-induced change, it is selectively inactivated. Loss of the antioxidant activity leaves the lubricant unprotected against attack by oxygen, which leads to formation of corrosive materials and deposits. Degradation products formed during irradiation of ester oils also greatly reduce the oxidation stability of inhibited lubricants.

Auto-oxidation proceeds through free radical chain reactions. Therefore, oxidation reactions would be accelerated during irradiation. The stability of inhibited oils, in oxidation-corrosion tests conducted in a gamma-ray source, decreased rapidly as the radiation dose rate was increased. At 400°F, a dose rate of 1.5×10^4 rep/hr shortened the stable life of a wide variety of antioxidant-oil combinations to approximately 70% of that obtained in absence of radiation. When the dose rate was increased to 7.2×10^5 rep/hr, only 25% of the original stability was retained. In oxidation tests at 347°F and dose rates of 7.2×10^5 rep/hr, only 12% of the unirradiated stability was found for various types of antioxidant-oil blends. The stable lives of all inhibited lubricants tested, in irradiated oxidation-corrosion tests at both 347°F and 400°F, appeared to be approaching zero at an estimated dose rate of $2\text{-}5 \times 10^6$ rep/hr. The total gamma-ray dose absorbed during the stable life of the various antioxidant-oil blends depended on the relative stability of the blend, the temperature of the test and the radiation dose rate, but in no case was it greater than 2×10^7 rep.

No protection against antioxidant radiation damage was found through use of radical scavengers or energy transfer agents (various iodine-containing compounds or aromatic materials). Base oil damage could be reduced through use of such materials, but the reactivity of antioxidants towards radicals was considerably greater than compounds added as protectors.

The dialkyl selenides show some promise for use with ester or hydrocarbon base oils at temperatures and radiation levels somewhat above those attainable with the more usual antioxidants. On an equal weight basis, the dialkyl selenides are slightly less effective than phenothiazine in imparting oxidation stability or in protecting ester base oils from radiation damage. However, they can be used in much higher concentrations without greatly affecting the deposit-forming tendency of the lubricant. The selenides must be kept from contact with copper and silver to avoid corrosion and loss of activity.

For use at bulk oil temperatures above 400°F or at total radiation doses of 10^8 rep or higher, inherently-stable, aromatic-containing materials will probably be needed. Preliminary work with specifically designed compounds has been directed towards determining the advantages and disadvantages of the various types of substituents and linkages that can be used with aromatic compounds. Tertiary butyl and carbomethoxy groups are promising substituents for use with benzene derivatives.

Silyl, ether, and ester groups can be used to link aromatic nuclei without large reduction in oxidation or radiation resistance. Preliminary examination of some of these synthetic compounds shows that their useful life, determined in oxidation tests at 400°F, would be at least 10 to 20 times longer than the most stable of the MIL-L-7808C ester lubricants. Additional aromatic derivatives are being prepared and examined in various high temperature screening tests.

WADC-TR-57-255 AD-131065

Matuszak Alfred H
NUCLEAR RADIATION RESISTANT TURBINE ENGINE LUBRICANTS,
Products Research Div., Esso Research and Engineering Co., Contract No. AF33(616)-3181, September (1957), 47 pp.

This report covers the results of work aimed at developing radiation resistant turbine engine lubricants. The work has been divided into two parts: (1) Phase I covering finished lubricants and (2) Phase II covering potential lubricating oil base stocks, all screened at dosages up to 10^8 roentgens.

In the Phase I program, twenty-four oils were screened. These included finished or slightly modified mineral-based aviation oils, ester-based synthetic lubricants and a polyalkylene glycol mono ether lubricant. At 10^7 roentgens no appreciable changes occurred in lubricant properties. At 10^8 roentgens, certain modifications of the mineral oils evaluated showed good retention of original physical and chemical properties. With uncompounded oils (Esso Aviation Oil 65 and 100) borderline performance was obtained in the MIL-L-7808 foam test and in the 347°F oxidation-corrosion stability test. These deficiencies can be partially overcome through the incorporation of additives. For improved oxidation-corrosion stability, phenyl-alpha-naphthylamine is beneficial. However, silicones are not very effective in maintaining foam suppression after irradiation. Additional work will be required to improve the foaming tendencies of mineral oils.

In the Phase II program twenty-three base stocks of varying chemical structures were screened at 10^7 and/or 10^8 roentgens. As in the case of Phase I lubricants the Phase II lubricant base stocks were evaluated against Military specification tests, notably MIL-L-7808 and MIL-L-9236. The most attractive materials evaluated were the inhibited mineral oil base stocks of which Barosa 56, a paraffinic base, is representative. Evaluation of this material at higher gamma dosages (5×10^8 and 10^9 roentgens) is contemplated.

In the future program this initial effort to develop a radiation resistant lubricant will be expanded to include the evaluation of other synthetic and petroleum-type finished oils and base stocks. Particular stress will be placed on higher flash base stocks, many of which are available commercially. Others may have to be synthesized. Any promising materials coming out of this screening program will be tested at higher gamma dosages. The most attractive base stocks will then be blended into finished oil formulations and finally evaluated further as radiation resistant engine lubricants.

WADC-TR-57-266 (Part I) AD-130807

Rice William L R, 1/Lt. (USAF) and Way James H, 1/Lt. (USAF)
EFFECTS OF NUCLEAR RADIATION ON ORGANIC FLUIDS. PART I. GAMMA RADIATION STABILITY OF CERTAIN MINERAL OILS AND DIESTER FLUIDS,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, June (1957),
21 pp. (6 refs).

A study was made of the stability to gamma radiation of certain refined petroleum oils and diester fluids. Testing of the irradiated fluids by means of lubricant evaluation procedures, such as viscosity, flash point, and oxidation-corrosion resistance, indicated that for the tests conducted, the mineral oils of the type studied should have general resistance to gamma radiation up to a dosage of about 1×10^8 roentgens. The diester fluid di-2-ethylhexyl sebacate (Plexol 201) had very poor stability to gamma radiation over the same range. Addition of 0.5% phenothiazine improved the radiation resistance of this base fluid, except for the loss of oxidative stability experienced at dosage levels of 1×10^7 roentgens and lower.

Examination was made of the test data for the irradiated fluids to determine if any property changes followed the radiation exposure history. This was to discover if either the mineral oil or diester-type fluids could be used as secondary reference standards for radiation calibration of nonuniform geometries exposed to nuclear radiation, such as bearing assemblies or circulating fluid loops. The changes offering the most promise

were the increase in neutralization number of the diester fluid and the gas evolution of the mineral oils.

WADC-TR-57-299 AD-155591

Rice W L R, 1/Lt. (USAF)
NUCLEAR RADIATION RESISTANT LUBRICANTS,
Materials Laboratory, Wright Air Development Center, ARDC, USAF, Wright-Patterson Air Force Base, Ohio, May (1958), 24 pp. (25 refs).

This report presents a summary of current information on the state of the art of nuclear radiation resistant lubricant development. Data are presented on the effects of gamma radiation on a number of commercial fluids and lubricants, with a discussion of potential problem areas. Advanced materials for extremely high temperatures and radiation exposures are discussed, and the present status of preferred lubricants is outlined.

Of the new base materials for use in extreme conditions of temperature and radiation, the polyphenyl ethers show the most promise. Relatively low melting compounds can be prepared that undergo minor change in 500°F oxidation-corrosion tests and form little coke at temperatures as high as 800°F. Stability during in-source oxidation-corrosion tests has been shown to be good. The major drawback to use of the polyphenyl ethers is their low temperature limitation. At present, the majority of these materials melt at temperatures in the range 100° to over 200°F.

WADC-TR-57-455 (Pt. 2)

Lavik Melvin T
HIGH TEMPERATURE SOLID DRY FILM LUBRICANTS,
Midwest Research Institute, Contract No. AF33(616)-3684, April (1958).

Four commercial solid dry film lubricants were submitted to gamma and neutron irradiation. Three of the films were resin-bonded mixtures of graphite and molybdenum disulfide. The other film was a mixture of lead oxide and graphite bonded with a glass-like material.

WADC-TR-57-465 AD-157459

Kinderman E M
EFFECTS OF HIGH-ENERGY, HIGH-INTENSITY ELECTROMAGNETIC RADIATION ON ORGANIC LIQUIDS,
Materials Laboratory, Wright Air Development Center, Contract No. AF33(616)-3738, July 5, 1957, 49 pp. (57 refs).

Effective development of practical nuclear power required that materials be developed to withstand its attendant nuclear radiation. For example among the materials which must withstand radiation in a nuclear-propelled aircraft are hydraulic fluids and lubricants. A knowledge of the effects of structure on the radiation stability of organic materials is of advantage in designing and producing such radiation-resistant hydraulic fluids and lubricants. This investigation attempts to provide such background information.

A series of organic esters, hydrocarbons, and miscellaneous compounds were subjected to radiation. A quantitative measurement of the amounts and kinds of radiation products

produced was made. From the observed products and their amounts, some inferences were made as to the stability of these materials and the influence that their structure had on their stability.

Radiolysis of organic liquids is influenced by structure. Molecules containing branch chain and benzyl groupings are more susceptible to radiolytic damage than are molecules containing only straight chain groupings. This greater damage may be explainable in terms of the greater inductive effects possible with the branch chain and benzyl groupings. Greater radiation stability is observed with higher molecular weight compounds. This effect may be explained in terms of the mechanisms of energy absorption and disintegration by the molecule.

Comparison of the radiolytic with mass spectrographic data shows some correlation between the modes of molecular disintegration induced in the two cases. The correlation is best when conditions of radiolysis are similar to those in the mass spectrograph, that is when radiolysis occurs in an essentially low pressure condition through activated species whose half-life is short and whose diffusion constants or reaction times are long.

Both electron and gamma radiation was used. The former received emphasis because of its speed and convenience in the test program. Comparison of the effects of the two types of radiation in six cases shows some quantitative differences in radiolytic yield. The products identified are the same, and the same structural effects are evident. The available data do not permit definite statements of equivalence between electron and gamma effects, although this is indicated.

WADC-TR-58-206 AD-202499

Wagner Robert M and Towle Leland H
EFFECTS OF HIGH ENERGY, HIGH INTENSITY ELECTROMAGNETIC RADIATION ON ORGANIC LIQUIDS,
Stanford Research Institute and Wright Air Development Center, Contract No. AF33(616)-3738, October (1958), 45 pp. (14 refs).

Materials employed for practical nuclear power applications must possess optimum resistance to radiation effects on their molecular structure. Although certain radiation effects are considered beneficial, the majority are degradative to an unacceptable degree at high dose levels. The functions of hydraulic and lubricating fluids in nuclear power auxiliary equipment are cases in point. These fluids must maintain viscosity and flash point at optimum levels. A knowledge of the effects of molecular structural characteristics upon radiolytic stability of organic materials is needed to aid in the efficient design of radiation-resistant equipment. Some materials may, of necessity, be located in a high flux density radiation field. This study attempts to provide, through the study of several representatives of different types of organic structure, background information which may suggest methods of judicious choice for a given application.

The following compounds were subjected to high energy electron bombardment: alkyl aromatic hydrocarbons, aromatic ethers, nitro aromatics, amino aromatics, and aliphatic mixed ether-alcohol types. Quantitative measurements were made of the amounts and types of radiolytic products formed. Inferences were drawn from such measurements concerning (1) the relative stability of compounds, and (2) the influence of functional groups upon satiability.

Higher molecular weight compounds in general, and condensed aromatic ring systems in particular, are the most resistant to radiation. Aliphatic or heterophatic linkages

between aromatic ring systems are sites of primary radiolytic scission.

The extent to which species of higher molecular weight than parent material are formed is directly dependent upon the fate of the initial products of the scission of each radiolytically labile linkage. The primary products of scission may (1) hydrogenate and revert to stable form; (2) if energetic enough, they may attack parent material; or (3) they may condense with each other producing products comparable to the parent in molecular weight.

Compounds possessing the ability to assume certain spatial configurations, allowing resonance effects to exist, may permit absorbed energy to be innocuously reduced to levels which are below that required to rupture the molecular structure.

The presence of different functional groups on aromatic ring systems markedly influence the mode of radiolytic scission. These differences are reflected in either gas yield, polymer yield, or both.

The data do not permit complete and unequivocal definition of either the mode of radiolytic decomposition or the delineation of the structure of all products detected.

WADC-TR-58-264

Fainman M Z, et al.
THE BEHAVIOR OF FUELS AND LUBRICANTS IN DYNAMIC TEST EQUIPMENT OPERATING IN THE PRESENCE OF GAMMA RADIATION,
Cook Electric Co., Contract No. AF33(616)-3865, March 31, 1958, 177 pp. (28 refs).

This report summarizes work conducted on a program designed to evaluate fuels, hydraulic fluids, and lubricants for use in a nuclear-powered aircraft. During the performance period ending March 1958, 79 fuels and 41 lubricants were investigated. Results obtained clearly indicate that it is necessary to assess the effects of mechanical, thermal, and radiation stresses simultaneously. It has been observed that mechanical tests in a radiation environment often affect materials more drastically and at lower doses of radiation that the same tests conducted with statically irradiated samples without attendant radiation. Relative ratings of ten of the most promising fuels and six lubricants with the best performance characteristics are given. These ratings are based on performance in dynamic test machinery operated in a radiation environment.

WADC-TR-58-683 AD-211915

Wagner Robert M and Towle Leland H
EFFECTS OF HIGH ENERGY, HIGH INTENSITY ELECTROMAGNETIC RADIATION ON ORGANIC LIQUIDS,
Wright Air Development Center, Wright-Patterson AFB, Ohio, Contract No. AF33(616)-3738, March (1959), 36 pp. (13 refs).

Practical nuclear power applications require organic materials which offer optimum resistance to the undesirable effects of radiation. Hydraulic and lubricating fluids in nuclear power auxiliary equipment are cases in point. Some of these may of necessity be located in a high flux density radiation field.

This study of several representatives of different types of organic structure was an attempt to provide background information which may suggest methods of judicious

choice for the efficient design of radiation-resistant equipment.

The following compounds were subjected to high energy electron or gamma bombardment: aromatic amines, aromatic nitro compounds, alkyl aromatic ethers, alkyl aromatic hydrocarbons, and aliphatic esters. In addition, alkyl aromatic compounds and aliphatic esters were subjected to high energy neutron bombardment.

The data do not permit either complete and unequivocal definition of the mode of radiolytic decomposition, or complete delineation of the structures of all products detected. Conclusions were drawn concerning:(a) the relative stability of compounds, and (b) the influence upon stability of the location and nature of functional groups. The conclusions derived from the thirty-month study are listed below:

1. Higher molecular weight compounds in general, and condensed aromatic ring systems in particular, are the most resistant to radiation. Aliphatic or heterocyclic linkages between aromatic ring systems are sites of primary radiolytic scission.
2. The extent of formation of species of higher molecular weight than the parent material is directly dependent upon the fate of the initial products of the scission of each radiolytically labile linkage. The primary products may either: (a) hydrogenate and revert to stable form, (b) attack parent material if energetic enough, or (c) condense with each other, producing products comparable to the parent in molecular weight.
3. Compounds not possessing the ability to assume certain spatial configurations cannot utilize otherwise available resonance energy dissipation processes. Such processes would permit absorbed energy to be reduced to levels below that required to rupture the molecular structure.
4. The presence of different functional groups on aromatic ring systems markedly influences the mode of radiolytic scission. These differences are reflected in either gas yield, polymer yield, or both.
5. There is no linear relationship between the amount of methylene insulation between two aromatic systems and differences in radiolytic stability.
6. Unsymmetrical phenyl loading of a short alkyl chain does not alter the degree of radiolytic stability.
7. Alkyl unsaturation introduced between two aromatic systems facilitates hydrogen transfer to the target but does not reduce the total radiolytic instability of the system.
8. There is no essential difference in the yield or the nature of radiolytic products when alkyl aromatic hydrocarbons and aliphatic esters are irradiated with gamma rays, electrons, or neutrons.
9. An oxygen-rich atmosphere did not effectively scavenge energy, and thus inhibit radiolysis damage during electron bombardment of either alkyl aromatic hydrocarbons or aliphatic esters.
10. Branching of aliphatic chains induces radiolytic instability in either esters or hydrocarbons.

WA-OMRO-13A-B1

Gisser H
THE EFFECT OF NUCLEAR RADIATION ON LUBRICANTS,
Pitman-Dunn Laboratories. Presented at Conference on Effects of Nuclear Radiations on Materials, October 1 and 2, 1957, Watertown Arsenal, Watertown 72, Mass., 23 pp. (8 refs).

This paper consists of a short review of recent work on the effects of radiation on lubricants and related fluids. Exposure of lubricants to radiation results in the formation of free radicals and the resulting changes in properties can best be understood in terms of the free radical reactions of the chemical systems involved. The materials are predominantly organic, and in the absence of oxygen the predominant reaction is the recombination of free radicals to build larger molecules, with the physical observation that viscosity increases with eventual solidification. In the presence of oxygen, free radicals initiate oxidation chains so that even at relatively low doses products of oxidation such as acids and compounds of lower molecular weight appear. With increased dosage, however, free radical combination eventually leads to solidification. At doses below 10^9 r, observed changes in physical and chemical properties depend on the compounds being irradiated. Mineral oils are less susceptible than aliphatic esters. Aromatic compounds are considerably more stable than aliphatic compounds due to free radical stabilization. The methylsilicones gel quite readily. Oxidation inhibitors, serving as radical traps, tend to reduce oxidation and radical combination at low dosages, but in many instances their effectiveness disappears rapidly as dosage is increased. Halides and particularly fluorocarbons yield appreciable quantities of strong acids.

The most promising direction toward development of stable materials is the use of aromatic groups in the molecules, the total structure being so designed to give the desired physical properties. Most of the work was done by gamma radiation using either cobalt-60 or spent reactor fuel elements. The behavior of conventional greases is similar to that of the base fluids from which they are made and here again, by the suitable selection of thickening agents and fluids having aromatic constituents, radiation susceptibility may be considerably reduced.

POLYMERIC MATERIALS, INCLUDING ELASTOMERS PLASTICS, AND ADHESIVES

ACSJ-0058

Williams T F, Matsuo H and Dole M
INHIBITION OF CRYSTALLIZATION IN POLYETHYLENE SUBSEQUENT TO GAMMA IRRADIATION,
American Chemical Society Journal, Vol. 80, p. 2595, (1958), (8 refs).

This is a brief one page discussion of inhibition of crystallization in polyethylene subsequent to gamma irradiation.

ACSJ-0458-1

Dole Malcolm, Milner D C and Williams T F
KINETICS OF UNSATURATION EFFECTS ON IRRADIATION OF POLYETHYLENE,
American Chemical Society Journal, Vol. 80, pp. 1580-1588, April-June (1958), (47 refs).

By studying three different types of polyethylene, it can be shown that the original unsaturation in the material whether vinyl or vinylidene disappears initially according to a first-order law and that the rate then becomes less than first order as the trans-vinylene concentration builds up. A protective action of vinyl groups by vinylene groups is postulated to explain the pronounced departure from first-order kinetics. Formation of vinylene unsaturation is accurately described by the equation $c - c_o = (c_\infty - c_o)(1 - e^{-kD})$ which is based on a linear increase of concentration with dose followed by a first-order elimination, both effects being independent of vinyl unsaturation. The limiting concentration attained is greater, the greater the crystallinity of the polyethylene. At liquid nitrogen temperatures vinyl destruction is virtually suppressed, but vinylene formation is scarcely affected. Approximately half of hydrogen elimination results in vinylene formation, probably by molecular detachment because of its zero temperature coefficient. A post-irradiation heating of the polyethylene to room temperature causes a significant amount of vinyl or vinylidene destruction, thus proving the existence of free radical reactions in the solid state. Evidence from infrared data for cyclization or ring link formation is given. Production of ring links is linear with time, and the greater the crystallinity of the polyethylene. The yield of ring links is less at liquid nitrogen temperature than at room temperature. The first-order kinetics observed for vinyl, vinylidene and vinylene elimination together with the high initial value of G_o for vinyl decay, 9.6, can only be explained on the basis of activation of the double bond of energy of excitation released in localized regions corresponding to the spurs of fast electron tracks. Thus this paper describes the kinetics of decay in the solid phase of a specific group whose chemical structure and concentration are both known.

ACSJ-0458-2

Schultz Allan R
CROSSLINKING EFFICIENCIES IN THE METHYL METHACRYLATE-ETHYLENE DIMETHACRYLATE AND ETHYL METHACRYLATE-ETHYLENE DIMETHACRYLATE SYSTEMS. DEGRADATIVE ANALYSIS BY ELECTRON IRRADIATION,
American Chemical Society Journal, Vol. 80, pp. 1854-1860, April-June (1958), (22 refs).

The intermolecular crosslinking efficiencies, ε, of ethylene dimethacrylate have been determined in four methyl methacrylate (MMA)-ethylene dimethacrylate (EDMA) copolymers and four ethyl methacrylate (EMA)-EDMA copolymers. Random scission of the copolymer networks by 100 kvp electrons was employed to determine the number of crosslinked units per gram. MMA-EDMA copolymers having EDMA mole fractions, N_2 of 0.00578, 0.00291, 0.00147 and 0.000868 exhibited ε-values of 0.39, 0.395, 0.44 and 0.48, respectively. EMA-EDMA copolymers with N_2 of 0.00675, 0.00333, 0.00172 and 0.00102 had ε-values of 0.32, 0.36, 0.38 and 0.39, respectively. The extrapolated efficiencies lim $\varepsilon(N_2 \rightarrow 0)$ are 0.46 and 0.40. These limiting efficiencies are consistent with the postulate of slightly greater than 50% loss of doubly reacted EDMA units to small intra-chain ring formation. The decrease in ε with increase in $\overline{N}_2$ in this low EDMA concentration range is in qualitative agreement with the limited accessibility concept of Loshaek and Fox for pendant double bond isolation on a polymer network.

AECD-2078

Burr J G and Garrison W M
THE EFFECT OF RADIATION ON THE PHYSICAL PROPERTIES OF PLASTICS,
Argonne National Laboratory, Lemont, Ill., December 6, 1943, 17 pp.

Changes in tensile strength and electrical resistivity as a result of β and γ irradiation are presented for 25 different plastics and synthetic rubbers. In certain cases, hardness and elasticity measurements are also given. It is shown that the rate, as well as the total amount of radiation, determines the resultant changes in physical properties. An attempt has been made to correlate the results in terms of the chemical and physical properties of the plastics.

Those plastics which can be used over a large thermal range are affected less with high-intensity radiation than those materials which have a low useful thermal range. Generally, plastics with a low initial specific resistance, i.e., 10^{10} to 10^{12} ohm-cm, show little relative change on irradiation. For plastics with high initial resistivity (i.e., $> 10^{14}$ ohm-cm), the effect of irradiation depends upon the amount and nature of added impurities. Those which contain the most impurity exhibit the greatest change in resistivity.

AECD-3634

Miller Arild J and Steel Gertrude
BEHAVIOR OF CERTAIN PLASTICS AND ELASTOMERS UNDER IRRADIATION, BASED ON WORK DONE DURING THE PERIOD 1942-1946,
Metallurgical Laboratory, University of Chicago, Chicago, Ill., Contract No. W-(7401)-Eng-37, (1948), 23 pp. (12 refs).

Data here presented show the effects of X-rays and electrons on the properties of various plastics and elastomers. The properties investigated were electrical resistance,

tensile strength, elasticity, hardness and optical properties, dependent on the proposed use of the material. In general, radiation causes a decrease in electrical resistance, tensile strength, elasticity and light transmission and an increase in hardness.

Five tables and two figures are included.

AECU-3516

VanWyck R W and Butler H L
INTEGRITY OF A PLASTIC SUIT IN TRITIUM ATMOSPHERE,
Paper proposed for presentation at the 1957 annual meeting of the Health Physics Society, E. I. duPont de Nemours Co., Health Physics Section, Works Technical Dept., Savannah River Plant, Contract No. AT(07-2)-1, January 14, 1957, 9 pp.

The integrity of a plastic suit in tritium contaminated atmospheres was determined. At contamination levels ranging from 10,000 to 100,000 times MPC levels, the level inside the suit is about 0.3% of the exposure level. Above this range, permeability of the suit increases rapidly. Penetration of the suit involves a time lag which offers protection against sudden bursts of activity.

AERE-E/R-2518

Wells H and Williamson I
THE DEGRADATION OF PLASTICISED P.V.C. COMPOSITIONS UNDER HIGH LEVEL GAMMA RADIATION,
Research Group, Atomic Energy Research Establishment, Harwell, Berkshire, England, May (1958), 18 pp. (5 refs).

Results are presented which indicate that polyvinyl chloride, plasticised with tritolyl-phosphate, is far less affected by gamma radiations than when plasticised with other conventional compounds.

AERE-GP/R-1402

Little K
THE EFFECTS OF HIGH DOSES OF IONIZING RADIATIONS ON ORGANIC HIGH POLYMERS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, March 22, 1954, 6 pp. (10 refs).

In observing the changes caused by ionizing radiation on high polymers it has been found that these changes depend upon the chemical nature of the polymers, and are different for each. The types of effects can be classified to a certain extent, but by no means completely, and attempts to do so seem to emphasize that each polymer must be considered as a chemical entity. Mechanical properties such as toughness combined with flexibility are likely to be good if polymers have a high melting point and high crystallinity (a 50% crystalline polymer is "highly crystalline").

Samples used were either in the form of textile fibers or polymer chips.

The conclusions reached suggest that polymers might be prepared which would retain desirable physical properties in a nuclear reactor for long periods, and all polymers can be expected to decompose about 350°C.

AERE-M/R-978

Charlesby A
THE DECOMPOSITION OF POLYTETRAFLUORETHYLENE BY PILE RADIATION,
Atomic Energy Research Establishment, Harwell, Berkshire, England, July 10, 1952, 7 pp. (1 ref).

To determine whether the presence of hydrogen atoms is necessary to permit crosslinking of polymers under irradiation, the behavior of PTFE was compared with that of polythene.

Under irradiation PTFE is found to break up, but there is no evidence of crosslinking. This effect which is mainly due to γ radiation is ascribed to the preferential fracture of C-C bonds in the main chain. No definite evidence is available that fluorine itself is liberated.

The change in weight ΔM with radiation dose R depends only on the surface area A, and not on the mass irradiated;

$$\Delta M = -\beta_2 A R^2; \beta_2 = 0.0125 \text{ mgms/cm}^2.$$

This equation is very similar to one of the mass loss terms found in polythene, where it is ascribed to the fracture of C-C bonds within the molecule, with subsequent evolution of hydrocarbons (such as CH_4, C_2H_6) only if they are liberated near the surface. In the case of PTFE the evolution of the analogous fluorocarbon CF_4 has been observed. In polythene the weight loss term $-\alpha_1$ MR is ascribed to the liberation of hydrogen. In PTFE, no such term is observed, nor has the analogous fluorine gas been detected among the gaseous products.

AERE-M/R-1003

Charlesby A and Ross M
THE EFFECT OF PILE RADIATION ON THE DENSITY AND MELTING OF POLYTHENE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, August 21, 1952, 18 pp. (16 refs).

The density of polythene has been studied in relation to temperature and the degree of crosslinking produced by pile irradiation. Crosslinking results in a progressive reduction in the percentage of crystalline material at room temperature. The transition temperature corresponding to melting in ordinary polythene is only very slightly decreased with increasing crosslinking, so that the temperature at which all crystalline structures vanish is little affected. However, because of the reduced amount of crystalline material present in the crosslinked polymer, the magnitude of the change in density at the transition temperature is considerably lessened. There are certain anomalies between the transition temperature deduced from density measurements and from other methods.

The density of crosslinked polythene in the amorphous state is found to obey a law very similar to the Van der Waals law for gases: -

$$\left(P + \frac{P_o}{1 - \beta c}\right)\left(V(c) - V_o\right) = RT/M$$

where P_o is the internal pressure arising from binding forces, V_o is a constant corresponding to a "residual" volume per gram at 0°K independent of the degree of crosslinking, and c and β are a constant close to unity. P represents the external pressure, V(c) is the specific volume (or volume per gram) of crosslinked polymer, and M is the molar weight $28(CH_2 - CH_2)$.

AERE-M/R-1034

Charlesby A
THE SOLUBILITY AND MOLECULAR SIZE DISTRIBUTION OF CROSSLINKED POLYSTYRENE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, November 18, 1952, 7 pp. (1 ref).

When exposed to pile radiation, polystyrene becomes crosslinked forming a network structure (or gel) which is insoluble in the usual organic solvents. Not all molecules are linked into the network; these remaining molecules form a sol which can be leached out by solvents.

On the assumption that all molecules are initially of the same size, Flory has obtained a theoretical expression for the sol fraction, i.e., the proportion of soluble material, in terms of the degree of crosslinking. In this paper a theoretical expression is derived for the sol fraction on the assumption that the molecular sizes are initially distributed at random, i.e., that they follow a Poisson distribution. This expression is extended to cover the case where both crosslinking and chain fracture occur, due to pile radiation.

Measurements of the sol fraction for polystyrene show that the latter formula fits the observed data. Thus the distribution of molecular weight in ordinary polystyrene is shown to follow a Poisson distribution. Chain fracture due to pile radiation is shown to be small or inexistent.

AERE-M/R-1051

Charlesby A
THE SWELLING PROPERTIES OF POLYSTYRENE CROSSLINKED BY HIGH ENERGY RADIATION,
Atomic Energy Research Establishment, Harwell, Berkshire, England, November 18, 1952, 7 pp. (5 refs).

The swelling properties of polystyrene, crosslinked by pile irradiation, are studied as a function of the degree of crosslinking. The volume swelling ratio V is related to the degree of crosslinking and the sol fraction s by the relationship:

$$V^{5/3} = (0.5-\mu)\, M_o/\gamma\, (1-s)\rho v_1 ,$$

where M_o is the initial average molecular weight, and μ, ρ and v_1, are known constants. The power factor (5/3) predicted on theoretical grounds is observed in the experiments. From the observed swelling in benzene and in toluene the average molecular weight M_o is found to be about 450,000. A similar value is obtained for the weight swelling ratio.

The method used in the paper may serve to determine molecular weights in other long chain polymers. Moreover, the swelling of polystyrene may serve as a means of

measuring the density flux of ionising radiations.

AERE-M/R-1060

Charlesby A and Hancock N H
THE INFLUENCE OF CROSSLINKING ON THE ELASTIC MODULUS OF POLYTHENE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, December 3, 1952, 11 pp. (5 refs).

The effect on Young's modulus E is studied when polythene is crosslinked by pile irradiation. Dynamic and static measurements of E are given at various temperatures and for varying degrees of crosslinking. At room temperature, E decreases at first with increasing crosslinking, resulting in a more flexible polymer. With further crosslinking E increases rapidly as a glass like amorphous structure is produced.

With increasing temperature E decreases up to a temperature of about 115°C when all crystallinity disappears. Beyond this point E increases with T, approximately obeying the relationship

$$E = n\rho P_g T/M_c$$

where ρ is the density, P_g the gas constant, T the absolute temperature, and M_c is the average molecular weight between crosslinks. The value of n obtained experimentally is approximately 2. For highly irradiated material, with about one crosslink per 2.5 carbon atoms, this formula no longer applies. The application of this formula to partly crystalline material is discussed.

AERE-M/R-1067

Ross Maurice and Charlesby Arthur
THE EFFECT OF PILE RADIATION ON POLYMETHYL METHAENYLATE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, August (1953), 6 pp.

Unlike many other long chain polymers, Perspex is broken up by high energy radiation in an atomic pile. Several of the changes produced are described, the most obvious being internal bubbling. The minimum radiation required for incipient bubbling depends on the temperature, e.g., 1.5-2 units at 70°C. Specimens exposed to shorter doses of radiation, although apparently unaffected, can be bubbled subsequently by heating. The suggested explanation of this phenomenon is the decomposition of the side chains of the polymer, liberating gases which, at a suitable temperature, can diffuse into bubbles. Polymer breakdown occurs when the internal gas pressure is sufficient to overcome the cohesive forces of the materials.

Bubbles do not occur within a distance of 1 mm from the surface of the plastic. This is ascribed to the diffusion of the decomposition products to the surface, provided they are liberated sufficiently close to it. A hypothesis of this character was previously put forward to account for the weight changes in polythene and is here confirmed visually in Perspex.

The possibility of producing an expanded form of Perspex by radiation and subsequent heating is discussed. This important article will be continued in a future issue.

AERE-M/R-1298

Charlesby A
MOLECULAR WEIGHT CHANGES IN THE DEGRADATION OF LONG CHAIN POLYMERS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, November 18, 1953,
10 pp. (2 refs).

The changes in molecular weight of a long chain polymer (initially of arbitrary molecular weight distribution) are studied when the main chain is subjected to random fracture, such as occurs when certain polymers are exposed to high energy radiation. For several distributions studied, all trace of the initial distribution curve is lost after some three to eight main chain fractures per molecule. For lower degrees of degradation, the shape of the weight average/degradation curve can provide information as to the initial weight average, z average, and z + 1 average molecular weights. The initial number average can be obtained by a method of extrapolation.

AERE-M/R-1342

Charlesby A
THE DEGRADATION OF CELLULOSE BY IONISING RADIATION,
Atomic Energy Research Establishment, Harwell, Berkshire, England, January 21, 1954,
6 pp. (11 refs).

When subjected to the effect of ionising radiation, such as atomic pile radiation or gamma radiation, cellulose is rapidly degraded into a powdery material.

A theoretical treatment shows that if the effect of radiation is to cause fracture at random in the main chain, the relation between intrinsic viscosity $[\eta]$ and radiation dose R should be of the form

$$\log [\eta] = -\alpha \log (R + R_o) + \text{constant}$$

where R_o is a "virtual" radiation dose needed to produce the initial number average molecular weight from a chain of infinite molecular weight.

The published data of Saeman, Millett and Lawton have been used to verify this formula, which leads to a relationship between $[\eta]$ in cupriethylene diamine and viscosity average molecular weight M_v

$$[\eta] = KM_v^{\alpha}$$

with $\alpha = 0.71$. The constant K has been evaluated by comparison with data given by Gralen, but is less accurately known.

It is deduced that one million roentgen results in fracture of 0.16% of the monomer units in the main chain. The decomposition of carbohydrates under radiation, which occurs at the same time as main chain fracture, can be explained on the assumption that approximately one monomer unit is decomposed per main chain fracture.

The study of intrinsic viscosity of irradiated polymers appears to offer an accurate means of evaluating α in the usual formula for intrinsic viscosity $[\eta] = KM^{\alpha}$.

AERE-M/R-1401

Ross M
CHANGES IN SOME PHYSICAL PROPERTIES OF POLYETHYLENE BY PILE IRRADIATION AT 80°C,
Atomic Energy Research Establishment, Harwell, Berkshire, England, April 2, 1954, 13 pp. (7 refs).

Changes are studied in the density, percentage of crystallinity and Young's modulus of polyethylene due to pile irradiation at about 80°C. It is shown that increasing the temperature during irradiation makes possible the production of amorphous material after a shorter irradiation time, and a wide variety of materials of varying density and different mechanical properties can be made. A new method of estimating the density of amorphous material in ordinary (unirradiated) polyethylene is outlined.

AERE-M/R-1442

Charlesby A
THE DEGRADATION OF CELLULOSE BY IONISING RADIATION,
Atomic Energy Research Establishment, Harwell, Berkshire, England, January 21, 1954.

When subjected to the effect of ionising radiation, such as atomic-pile radiation or gamma radiation, cellulose is rapidly degraded into a powdery material. A theoretical treatment shows that, if the effect of radiation is to cause fracture at random in the main chain, the relation between intrinsic viscosity (n) and radiation dose, R, should be of the form

$$\log(n) = -\text{alpha} \log (R + R_o) + \text{constant},$$

where R_o is a virtual radiation dose needed to produce the initial-number average molecular weight from a chain of infinite molecular weight.

AERE-M/R-2159

Worrall R
THE GAMMA AND PILE IRRADIATION OF POLYTETRAFLUOROETHYLENE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, January 1957, 12 pp. (15 refs).

Fluorine is evolved on gamma and pile irradiation of polytetrafluoroethylene (PTFE) and continues to diffuse out of the polymer after irradiation.

Except for thin specimens, the total fluorine evolved (determined as fluoride F^-) is dependent on the surface area A and on the radiation dose R:

$$F^- = \beta A(R)^{1.2}$$

where $\beta = 0.0025$ mg/cm^3/(10^6 roentgen)$^{1.2}$ for gamma irradiation,
and $\beta = 0.17$ mg/cm^2(unit)$^{1.2}$ radiation for pile irradiation.

An equivalence of pile radiation is obtained which is in reasonable agreement with that obtained by calorimetry.

AFSWP-241

Bates W J and Kelly M J
THE RELATIVE PROTECTION AGAINST RADIATION BURNS PROVIDED BY HEAT-TREATED ORLON,
Material Laboratory, New York Naval Shipyard, Brooklyn 1, N.Y., August 13, 1952.

The protection against radiation burns afforded by heat-treated Orlon was investigated, by comparing the protection given by the Orlon with that given by other representative clothing fabrics of comparable weight. The textile properties of heat-treated Orlon are discussed, indicating that, although the heat treatment causes the Orlon to lose much of its original strength, the properties of the heat-treated Orlon, are favorable when compared with other clothing fabrics. Beef muscle tissue was used in contact with the back of the cloth as a human skin equivalent. Upon irradiation, the temperature rise of the interface of the fabric and meat in contact was determined as a measure of the protection afforded. A correlation of temperature rises between a small blackened copper disc and the beef was determined to facilitate the measurements. A theoretical analysis of the problem was made to determine the temperature change at the interface of the cloth and meat upon radiation. The experimental study showed that the heat-treated Orlon, in comparison with other fabrics of similar weight when used as a single garment in contact with the skin, offered no greater protection than the standard cloths except for radiant exposures of more than 30 cal/cm^2. Cotton and wool are destroyed by this radiant exposure while the Orlon remains intact.

APEX-261

Collins C G and Calkins V P
RADIATION DAMAGE TO ELASTOMERS, ORGANIC LIQUIDS, AND PLASTICS,
Atomic Products Div., Aircraft Nuclear Propulsion Dept., General Electric, Evendale, Ohio, Contract No. AF33(038)-21102 and AT(11-1)-171, September (1956), 245 pp.

This report presents a collection of the available data on radiation damage to materials that are of value for engineering purposes. An attempt has been made to generalize, categorize, and evaluate the data, as well as reducing dosages to a common basis for comparison. This report is comprised principally of tables and graphs of experimental data on elastomers, plastics, and organic liquids.

ASTM-0057

Sisman O and Bopp C D
A SUMMARY OF THE EFFECT OF RADIATION ON SOME PLASTICS AND ELASTOMERS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Symposium on Radiation Effects on Materials published by the American Society for Testing Materials, (1957), 11 pp.

As a result of the absorption of high-energy radiation, organic solids undergo rather complicated chemical reactions which are not yet fully understood in even the most simple polymers. Two general classes of reactions have been recognized, however, which can explain most of the changes that are observed in the physical properties of plastics and elastomers. The reactions are called cleavage or scission and crosslinking. The crosslinking reaction results in the binding together of the molecules of a polymer into a network structure such as is found in a gel. The cleavage reaction, as the name implies, breaks down the long polymer chains into smaller fragments.

Two main topics are discussed. These are reaction mechanisms and how the formation of crosslinks and the breaking up of molecules by cleavage will affect the mechanical properties of solids.

Irradiation induced changes in the mechanical properties of plastics and elastomers are discussed. It is pointed out that these property changes depend upon the rates of cross-linking and cleavage.

BMI-125A-1

Restaino A J
METALLO-ORGANIC POLYMERS,
The Martin Company, Baltimore, Md. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 8 pp. (9 refs).

This paper discusses organic polymers containing metals. Tables are included in which is given the effect of gamma irradiation on the rate of polymerization of metal acrylates; the effect of metal polymer compositon on tensile strength and elongation; the effect of gamma radiation on the tensile strength and elongation of some metal-organic polymers; the composition and properties of some newly developed metallo-organic polymers; and the swelling ratios of metallo-organic polymers in various solvents at 22°C. The metals used in these polymers is lead, lithium, and uranium.

BMI-125A-2

Bauman R G and Born J W
THE MECHANISM OF RADIATION DAMAGE TO ELASTOMERS,
B. F. Goodrich Company Research Center, Brecksville, Ohio. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 5 pp. (6 refs).

Although the effectiveness of anti-rads (chemical inhibitors of radiation damage) in rubber is known emperically, our knowledge of their mode of action has been only speculative. Continuous stress relaxation studies were made in an attempt to learn details of their effectiveness in preventing chain scission of elastomers. Analysis of the results of relaxation in air and in nitrogen reveals that the anti-rads are in general more effective in preventing radiation-induced oxidative chain scission than nonoxidative chain scission.

When a rubber sample is stretched to a given degree of strain and held fixed at that strain, the stress gradually decreases. This phenomenon is termed stress relaxation.

This paper has two tables: stress relaxation rates of various elastomers and the effect of anti-rads on chain scission. A photograph is included which shows the stress relaxation reader assembly.

The material compounded and vulcanized to serve as control stock in the study of anti-rads was natural rubber, SBR, Neoprene GN, Hycar 1002, and butyl rubber. Two separate series of stocks containing anti-rads were prepared. In one series 5 pphr of beta-naphthyl amine was compounded into each base recipe. In the other series anti-rads were separately compounded into carbon black-reinforced natural rubber recipe in the amount of 5 pphr. The results are discussed.

BMI-125A-3

Dirkes W E
REINFORCED PLASTICS AND STRUCTURAL ADHESIVES,
WADC, Wright-Patterson Air Force Base, Ohio. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 4 pp. (7 refs).

A summary is presented of the Materials Laboratory internal and contractual studies of nuclear radiation effects on structural plastic materials. Transparent materials used for aircraft glazing, thermosetting plastics reinforced with glass cloth, and structural metal-to-metal adhesive bonding materials have been irradiated. Thresholds of degradation vary from 10^7 ergs/gm for transparent plastics to about 3×10^{12} ergs/gm for glass cloth reinforced plastics. Each material was investigated in terms of the properties considered essential for use in airframes.

Structural adhesives used to bond metals have also been exposed to gamma radiation at WADC. WADC Technical Report 56-467 contains an evaluation of strength degradation for vinyl phenolic, nitrite rubber phenolic, nylon phenolic, epoxy, and epoxy phenolic adhesives. The properties determined were tensile shear, bend, and fatigue strengths at room and elevated temperatures.

Loss of nearly one-half the initial strength occured in one adhesive at an exposure of about 10^{10} ergs/gm. In general, the materials tested showed a loss of one-third the initial strength around 5×10^{10} ergs/gm, while one adhesive had very little loss in strength with an exposure of nearly 10^{11} ergs/gm.

BMI-125A-4

Lightfoot R P and Rivera W H
PROBLEMS WHICH ARISE DURING ENGINEERING EVALUATION OF RADIATION EFFECTS ON ORGANIC MATERIALS,
Convair Div., Fort Worth, Tex. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 17 pp. (7 refs).

Engineering evaluation of radiation-induced physical property changes in plastics and elastomers is needlessly complicated by the lack of complete data concerning materials and procedures. Problems encountered in correlating data from various test facilities are enumerated and discussed with points of major concern graphically illustrated. Recommendations for uniformity in reporting of radiation effects data are presented.

BMI-125A-5

Fischer D J and Warrick E L
POST-IRRADIATION CHANGES IN SILICONE RUBBER,
Dow Corning Corporation, Midland, Mich. Paper presented at the Second Semi-Annual 125A Radiation Effects Symposium, Battelle Memorial Institute, Columbus, Ohio, October 22-23, 1957, 5 pp.

The great majority of radiation studies of elastomeric compounds assume that the effects observed immediately following radiation are the only phenomena which occur. Silicone rubber shows marked time effects as changes in physical properties for a

number of days following irradiation. Studies of the stability of materials should consider such post irradiation changes.

The crosslinking effect of radiation on elastomeric materials has been shown to correlate well with dose. Indeed some have suggested that this might be used for dosimetry. The experience of the authors in crosslinking simple silicone rubbers led them to believe that such a linear correlation existed between the dose of gamma radiation and the number of crosslinks established. Six months after obtaining such data it became necessary to check some values and they were quite surprised to find the crosslinking level greatly increased. At some dose levels the number of links nearly doubled. A systematic study of the phenomena is under way. Not all aspects of the time effect are clear, but it does seem to be enhanced by the presence of oxygen. Presumably this is similar to the effect observed by Sears as oxidative changes in radiated styrene and deprotenized natural rubber. Miller and Lawton also show an oxidative time effect for polyethylene. One must be certain that the magnitude of such time effects are known or are entirely absent before one can be assured of the stability of a material toward radiation exposure.

BNL-141(T-27)

Manowitz B, Horrigan R V and Bretton R H
PRELIMINARY STUDIES ON INDUSTRIAL APPLICATIONS OF INTENSE GAMMA RADIATION,
Fission Products Utilization Project, Research Div., Reactor Science and Engineering Dept., Brookhaven National Laboratory, Upton, N.Y., December 1, 1951, 15 pp. (5 refs).

This report presents the results of preliminary studies on industrial applications of intense gamma radiation and is part of a program to study the possibilities for the utilization of the radioactive wastes produced as byproducts of plutonium separation processes.

Radiation sources are discussed, and it is pointed out that a considerable amount of effort has been put into the production of intense gamma radiation sources to be used for application development.

The AEC is supporting research programs in gamma radiation application at several universities. These experimental programs are discussed.

Another purpose of this investigation is to determine the kinetics of styrene polymerization under the influence of gamma radiation. The theory is discussed. The procedure for purification and preservation of the styrene monomer is outlined. This procedure is used by the Eastman Kodak Co. to produce chemical grade styrene, stabilized with tertiary-butyl catechol.

A discussion of the results of the preliminary studies is included.

BNL-229(T-35)

Ballantine D and Manowitz B
PROGRESS REPORT ON FISSION PRODUCTS UTILIZATION. V. - THE POLYMERIZATION OF VINYL MONOMERS BY INTENSE GAMMA RADIATION,
Brookhaven National Laboratory, Upton, N.Y., March (1953), 13 pp. (15 refs).

The gamma-ray induced polymerization of styrene and methyl methacrylate has been investigated and has been shown to be free radical in nature. Both monomers show a constant rate of polymerization in the initial stages followed by a rapid increase similar to a "Trommsdorf" effect. Molecular weight increase occurs with the increased rate. There is some indication of surface effect on polymerization rate and of crosslinking of polymer. Activation energies for combined propagation and termination rates have been calculated and agree well with published values for free radical polymerizations involving bimolecular termination. Experimental results are discussed and future plans outlined.

BNL-294(T-50)

Ballantine D S
PROGRESS REPORT ON FISSION PRODUCTS UTILIZATION. VI. - FURTHER STUDIES OF THE EFFECT OF GAMMA RADIATION ON VINYL POLYMER SYSTEMS, Brookhaven National Laboratory, Upton, N.Y., March (1954), 18 pp. (23 refs).

The initiation of polymerization by gamma radiation has been extended to emulsions of styrene at various temperatures. The rates are faster and molecular weights higher than those obtained in bulk polymerizations at similar temperatures.

The monomer N-vinylpyrollidone has been polymerized in aqueous solutions under varying conditions of intensity, temperature, and solvent composition. The polymer is manufactured under the name "Plasdone" and is used as a blood plasma substitute. Data on rate and K value (an empirical index of molecular weight) are given.

A series of perfluoromonomers were irradiated in an attempt to cause polymerization, but the rates observed were extremely low as was the molecular weight of the polymer produced.

Acrylamide, a monomer with melting point of 84.5°C, has been polymerized in the solid state by means of gamma rays. Rate and molecular weight data from experiments at various intensities and temperatures are reported.

Commercial polyethylene films and rods have been irradiated with gamma rays, and quantitative measurements of the physical properties such as tensile strength, creep and heat deformation were made. In general, radiation produces an improvement in heat stability but deleteriously affects tensile and elastic properties.

BNL-317(T-53)

Ballantine D S and Manowitz B
PROGRESS REPORT ON FISSION PRODUCTS UTILIZATION. VII. - STATUS REPORT ON THE GAMMA-RAY INITIATED POLYMERIZATION OF N-VINYLPYROLLIDONE, Brookhaven National Laboratory, Upton, N.Y., October (1954), 7 pp.

Gamma radiation from cobalt-60 has been used to polymerize N-vinylpyrollidone in an attempt to produce a polymer that might have use as a blood plasma expander of better quality than the commercial polymer. A study has been made of the effect of monomer concentration, temperature, gamma-ray intensity, and solvent composition on the polymerization rate and average molecular weight.

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It has been found that rate depends upon monomer concentration to the first power and that average molecular weight increases with increasing monomer concentration. Material of desirable average molecular weight was produced at 1 to 2% monomer concentrations in water.

Temperature increase caused an increase in rate but had little effect on average molecular weight.

Increasing intensity of the gamma radiation caused increase in rate but decrease in average molecular weight.

The polymerization rate and average molecular weight decreased as water was replaced with alcohol and chlorinated solvents.

The polymer produced by radiation has a narrower molecular weight distribution, and it was found that radiation of the polymer caused a decrease in average molecular weight.

BNL-2275

Ballantine D, Glines A and Manowitz B
GAMMA-RAY INITIATED POLYMERIZATION OF N-VINYLPYROLLIDONE,
Brookhaven National Laboratory, Upton, N.Y., (1954), 5 pp. (3 refs).

See BNL-317(T-53) for complete abstract.

BOE-D2-1819

DeZeih C J
EFFECTS OF NUCLEAR RADIATION ON CORK, LEATHER, AND ELASTOMERS,
Boeing Airplane Company, Seattle 24, Wash., June 25, 1957, 23 pp.

Samples of cork, leather, and various elastomers were irradiated in the cobalt-60 gamma source of the California Research Corporation at dosages of ca. 10^7 to 10^{10} ergs/gram.

No significant changes were observed for cork. Tensile strength of leather was affected; no hardening was noticed. These materials can be used in certain systems in nuclear environments. Elastomers SE-551 and SE-371 are affected by nuclear radiation. At ca. 10^{10} ergs tensile strength and elongation properties decrease considerably, while hardness increases to the point of crumbling. High temperature Thiokol exhibits good properties after irradiation.

Viton A retains usable tensile strength up to ca. 10^{10} ergs, with some increase in hardness. At ca. 10^{10} ergs the percent of elongation of Viton A drops considerably.

Viton A and high temperature Thiokol appear to be promising materials for use in nuclear environments.

BRC-7238

Ballantine D S, Glines A and Metz D J
THE ROLE OF OXYGEN IN THE POST-IRRADIATION GRAFTING REACTION,
Brookhaven National Laboratory, Upton, N.Y., April (1958), 9 pp. (8 refs).

If a high polymer is subjected to ionizing radiation and a vinyl monomer added to it in a postirradiation step, a graft of block copolymer is formed. This reaction can occur via two mechanisms: the first involving peroxides formed in the irradiation step if oxygen was present, and the second involving trapped free radicals formed during irradiations in vacuum. There is also evidence for some trapped free radicals in the oxygen irradiation. This paper discusses the efficiency of the reaction involving polyethylene and styrene monomer as a function of dosage, dose rates, temperature, and atmospheric environment during irradiation as determined by chemical analysis. The results are in agreement with the mechanism suggested. Some preliminary electron paramagnetic resonance results are in essential agreement with the hypothesis. The half lives of the trapped free radicals in polyethylene vary with temperature and atmosphere, but if maintained in vacuum at room temperature they are at least 6 months long.

CF-51-11-144

Watson C D and Tyner M
RADIATION DAMAGE STUDIES - PAINTS, PLASTICS, INSULATORS, AND STAINLESS STEELS,
Unit Operations Section, Chemical Technology Div., Oak Ridge National Laboratory, Oak Ridge, Tenn., November 10, 1951, 7 pp.

This report discusses the exposure to gamma irradiation of several plastic paints, Teflon plastic, two types of electrical insulators, and three common types of stainless steel.

The plastic paints irradiated were commercial brands of nonstrippable maintenance coatings painted on ARCO concrete specimens. The electrical insulators exposed were synthetic mica and porcelain. Welded and nonwelded specimens of 347, 309, and 316 stainless steels were exposed in the presence of 20% HNO_3.

COO-196

Brownell L E, et al.
UTILIZATION OF THE GROSS FISSION PRODUCTS - PROGRESS REPORT 5,
Engineering Research Institute, University of Michigan, Ann Arbor, Mich., Contract No. AT(11-1)-162, September (1953), 186 pp.

This report describes the work accomplished since Progress Report 4 (COO-124), dated March 1953, was prepared. The experimental studies detailed in this report may be summarized as follows:

The fundamental study of the effect of radiation on combustion (sub-project M943-2) has continued and the experimental equipment has been used successfully; however, as yet experimental difficulties have not permitted the comparison of explosion-limit curves with and without the influence of beta-particle radiation. This study will be completed as a portion of the studies on the effect of radiation on chemical reactions (sub-project M943-4).

The study of performance of combustion engines under the influence of radiation (sub-project M943-3) has been continued with tests on drag-stabilized hydrocarbon-air flames under the influence of radiation from 2050 curies of gold-198. The results of these tests indicate that more efficient combustion is obtained when radiation intensity is high.

These tests were concluded with support from Michigan Memorial-Phoenix Project 83.

The study of the effect of radiation on the promotion of chemical reactions has been continued with studies on the polymerization of ethylene and the chlorination of benzene and toluene. Initial studies indicate that the chlorination of toluene gives the hexachloro addition product. A discussion of the thermodynamics and kinetics of reactions is included.

Dosimetry studies on both the 1-kc and 10-kc sources are reported, and the nominal activities and those determined from dosimetry measurements are compared. The actual activity of both the 1-kc and 10-kc sources is found to be considerably less than the reported activity. Personnel of Brookhaven National Laboratory have reached the same conclusion regarding the true activity of the 1-kc source, based on reactor computations.

The Michigan Memorial-Phoenix Projects have used gamma radiation in a number of studies which are reported. Phoenix Project 41 is supporting an extensive animal-feeding experiment using gamma-irradiated food. The original plan of the feeding experiment reported in Progress Report 4 has been modified to include one diet in which all the food is irradiated. Personnel of Phoenix Project 54 have treated large sections of trichinous pork with gamma radiation using both the 10-kc cobalt source and radiation from spent reactor fuel slugs. A preliminary design for a pork processing plant to handle 2000 hogs per day indicates that the irradiation of pork using waste fission products would require 1-1/2 megacuries of fission products and would increase the cost of the pork approximately 2.3 mills per pound. Various designs of irradiation chambers are considered.

Michigan Memorial-Phoenix Project 73 is supporting an investigation of the nutritive value of irradiated media using the protozoan Tetrahymena Pyriformis as the test organism. The requirements of this protozoan for the essential amino acids and the B vitamins are very similar to those of man. The short life cycle of this organism compared to experimental animals such as rats should accelerate the accumulation of data on this problem.

Preliminary studies of the effect of radiation on rubber and on polymerization have been initiated with the support of Phoenix Project 43. The nature of the polymer, the action of compounding agents, and possibly the degree and nature of cure all influence the resistance of a given rubber formulation to gamma radiation.

The gamma-catalyzed polymerization of a mixture of styrene and methyl methoxylate appears to be a free-radical process; however, the gamma-catalyzed polymerization of styrene is mildly promoted by several rubber antioxidants and vulcanization accelerators and is retarded by sulfur, dinitrobenzene, and other materials.

Academic studies in the Department of Bacteriology by N. J. Williams on the irradiation of human blood culture media indicate that radiation sterilization of media is not feasible because changes are produced which alter the growth of certain organisms on the irradiated media.

The new 1-kc gamma source has been installed in the Fission Products Laboratory and has been in satisfactory operation for several months. It was found necessary to add concrete shielding to the ceiling of the radiation "cave" in order to reduce radiation effects in nearby buildings to levels approved by the Radiation Policy Committee of the

University of Michigan. Some difficulty has been experienced in controlling the pH and clarity of the water in the well of the radiation cave; however, to date no corrosion of the aluminum jackets of the cobalt rods is evident.

Academic studies on the use of polyvinyl chloride films in dosimetry measurements has been conducted by L. M. Welshans. Procedures for preparing and using these films and modifications of published techniques are reported and discussed.

COO-198

Brownell L E, et al.
PROGRESS REPORT 6 - UTILIZATION OF THE GROSS FISSION PRODUCTS, Engineering Research Institute, University of Michigan, Ann Arbor, Mich., Contract No. AT(11-1)-162, March (1954), 249 pp.

Performance tests were made with a diesel engine using 1000 curies of palladium-109 in the combustion chamber. No significant improvement in performance was observed.

Ethylene was polymerized under gamma radiation at pressures of about 1000 psi and room temperature. Radiation dosages of 5 to 7 megarep produced a hard tough polymer having a tensile strength up to 2300 psi with 79% elongation upon rupture, and a molecular weight of 37,300. Lesser dosages of radiation produced a soft, brittle, waxy polymer. Toluene was chlorinated under gamma radiation and produced the addition compound. This reaction is considered to be unique in that it is believed to be promoted only by gamma radiation. The product toluene "hexachloride" is being evaluated as an insecticide.

In organoleptic studies on irradiated food the problem of flavor in irradiated food, the design of experiments for flavor evaluation, and the use of statistics in experimental studies are discussed. Experimental results are reported from a taste panel in which the triangle tests and incomplete block ranking tests were used. Pasteurization and sterilization doses of gamma radiation were used in the studies on fresh fruits. The pasteurization and storage life of meat at refrigerator temperature were investigated. Flavor and texture changes were slight in irradiated fresh peaches, dark sweet cherries, and cooked applesauce. Test panel tests showed that the shelf-life of pasteurized ground pork stored at 40°F could be lengthened to 10 days and possibly longer; ground beef to 8 days. Taste panel tests on irradiated cooked meat indicated that by the combination of heat and gamma radiation it may be possible to sterilize canned meat without undesirable flavor changes.

A new method of wholesaling meat is proposed, based on the prepackaging of meat at the packing house followed by pasteurizing with gamma radiation. Advantages of this process to the retailer, wholesaler, and consumer are discussed. A design for a commercial radiation facility is presented. Separated cesium-137 is selected as a gamma source over 3, 6, 12, and 24 month old fission products on the basis of radiation characteristics and cost. By use of multipasses and by interception of a greater percentage of the radiation flux the efficiency of utilizing radiation was increased five fold over that of a previous design.

Research reported by the Michigan Memorial Phoenix Project includes the animal feeding experiments using irradiated food, Tetrahymena, for the evaluation of the effects of gamma radiation on essential nutrilites, gamma ray sterilization of canned meat, aerobic growth of micro-organisms in raw beef exposed to sublethal ("pasteurizing") dosages of

radiation, and gamma ray sterilization of tissue culture media.

In the pilot studies with animals fed irradiated food no acute toxicity was observed in animals fed food receiving a 20 megarep radiation dose. However, a marked vitamin deficiency was observed when the complete diet was irradiated with this dosage. This deficiency was removed by supplementing the diet with the water soluble vitamins. Long term feeding and breeding experiments are underway using a colony of 124 initial animals (albino rats) and a diet receiving 4 megarep.

A completely synthetic medium was prepared consisting of the essential amino acids and vitamins required by Tetrahymena. The individual constituents were irradiated in solution and tested for their ability to support growth of the protozoa. These tests showed that thiamine, riboflavin, pantothenate, pyridoxine, folic acid, and thioctic acid were destroyed by irradiation in dilute solution by less than 1×10^6 rep, while 2×10^6 rep was required to inactivate niacin. Most amino acids proved to be relatively radiation-resistant.

Clostridium botulinum 62A and Putrefactive anaerobe NCA 3679 were used on the tests with canned meat. The sterility dosage for canned meat was found to increase from 2.5 to 4 million rep as the concentration of Clostridium botulinum spores is increased from 4 to 40,000 per gram.

Raw beef exposed to 40,000 to 160,000 rep was stored for 13 days at $40^{\circ}F$ without the development of the off odor of putrid meat; but such an off odor and a slimy growth developed in samples receiving a dose of only about 20,000 rep and stored under similar conditions. Bacterial counts made in this study showed a time lag in the growth of micro-organisms in the irradiated meat indicating a decrease in population.

A radiation dosage of 10^6 rep destroyed nonspore-forming organisms in tissue culture medium without detriment to the growth-promoting and tissue-sustaining properties of the medium as measured over a short time.

Studies undertaken cooperatively with industry included the gamma irradiation of glass fibers, of beer, and of cut flowers. The evaluation of results in each case was made by the industrial laboratory concerned.

Glass fibers exposed to gamma radiation had a lower tensile strength than the controls, for reasons undetermined. The Young's modulus of glass is not appreciably affected by large amounts of gamma irradiation.

Gamma radiation does not appear promising as a substitute for heat for the pasteurization of beer because dosages sufficient to destroy the brewery organisms also change the odor, color, taste and clarity of the beer.

Roses packaged in polyethylene and irradiated with doses up to 10^5 rep kept twice as long at room temperature as the controls and were perfectly preserved after 30 days' storage at refrigerator temperature.

Routine operation of the laboratory has continued according to plan. Wooden equipment in the radiation cave failed under normal load as a result of long-term radiation damage. The design of the ion exchange equipment used to treat the water in the cave well is described.

Faraday-12

Collinson E and Dainton F S
THE X-RAY AND GAMMA-RAY INDUCED POLYMERIZATION OF AQUEOUS SOLUTIONS OF ACRYLONITRILE,
Reprint from Discussion of the Faraday Society, Vol. 12 (1952), 14 pp. (14 refs).

Polymerization induced by the action of radium gamma rays, 220kV and 50kV X-rays on aqueous solutions of acrylonitrile has been studied. Radiation dosimetry was by measurement of the oxidation of ferrous ions in all cases. Polymerization in D_2O solution, followed by infra-red spectroscopic analysis of the polymers produced gave direct proof of the formation of D-atoms in the irradiated liquid, and confirmed their participation in the polymerization.

The kinetics of the polymerization were studied over the available concentration range, and with dose rates ranging from 6.6×10^{12} to $33,400 \times 10^{12}$ ion pairs/ml min. At low dose rates the kinetics were consistent with a nonuniform distribution of the radicals formed from the water, while at high dose rates an increasing degree of uniformity was indicated. There was apparently no difference in the effects produced by the three types of radiation.

A possible explanation of these results is that all three radiations give rise to randomly distributed volume elements of radicals in water in which chemical reaction takes place, the volume elements being widely separated and independent of each other at low dose rates but tending to overlap at high dose rates. Though this hypothesis is not finally established the viscosity molecular weights of the polymers showed a dependence on dose rates which is in general agreement with it.

FZM-1028

Newell D M
IRRADIATION OF PLASTICS AT GODIVA,
Paper presented at the Second Annual 125A Radiation Effects Symposium, October 22-23, 1957, Convair, Div. of General Dynamics Corporation, Fort Worth, Texas, 16 pp. (6 refs).

(This is Proprietary)

GEL-57

Ryan J W
EFFECTS OF RADIATION ON ORGANIC MATERIALS,
General Electric Laboratory, General Electric Co., Schenectady 5, N.Y., December 5, 1952, 31 pp.

A study of certain insulating materials and varnishes by gas evolution, tensile strength, elongation, and creep and abrasion resistance is presented and discussed.

The inorganic materials (mica and phosphoasbestos papers) are relatively unaffected by in-pile irradiation. A silicone (81132), a phenolic (9555), and Formex were tested. The Formex could not take the temperature of the Brookhaven pile (160-180°C); #81132 appears to be better than the 9555.

HDC-1876

Peterson D L
PRELIMINARY RUBBER IRRADIATION TESTS,
Reactor Design Division, Hanford Works, General Electric Co., Richland, Wash., August 25, 1950, 6 pp.

The tests presented in this report were proposed to give necessary information on the effect of intense irradiation on various synthetic and natural rubbers. This information is necessary to properly evaluate a proposed design for a synthetic rubber gland on the discharge end of the process tubes. Such an outlet would be used in connection with "segmented" or continuous discharge of metal.

All samples tested began to lose springiness at 7.52×10^{12} nvt average exposure. At 14.14×10^{12} nvt all samples were still fairly springy, but surfaces were becoming hard and shiny.

The conclusion reached is that none of the samples tested can be considered for use in seals, flexible connections, flexible shielding or similar applications where a high neutron flux exists.

HW-37960

Cooke J P
FINAL REPORT PRODUCTION TEST 105-585-A, FINAL TESTING OF TEFLON FLEXIBLE CONNECTOR, 105-C TYPE,
Pile Technology Sect., Engineering Dept., Hanford Works, Richland, Wash., June 15, 1955, 6 pp. (3 refs).

A new type of flexible hose connector consisting of a Teflon tube enclosed in a stainless-steel wire braid sheath was proposed for use on 105-C rear face in late 1954. A test was initiated to determine the suitability of Teflon, and specifically Fluoroflex Teflon compound for rear face application.

Failure of the connector after approximately eight months service was due to stress corrosion of the stainless-steel braid caused by HCl which was liberated during the decomposition of a polyvinyl coating used to keep surface contamination out of the braid. Physical tests of specimens of Teflon cut from the section of tubing when correlated with other tests indicated that it had been exposed to an irradiation dose of 100,000 to 300,000 H. Fluoroflex Teflon compound is both stronger and more flexible than the ordinary white variety, and even after 10^6 R, tests have still shown strength approximately that of unirradiated white material, with considerably greater stretch before break. Probable useful life limit is estimated at 10^6 R, which would be attained in about three years in contact with fresh effluent. A softer temperature stainless-steel wire would undoubtedly be less subject to stress corrosion.

HW-44092

Harrington Robert
PLASTICS AND ELASTOMERS FOR USE IN RADIATION FIELDS - EFFECTS OF GAMMA IRRADIATION,
Reactor and Fuels Research and Development Operation, Hanford Atomic Products Operation, Richland, Wash., Contract No. W-(31-109)-Eng-52, November 30, 1956, 41 pp.

This report summarizes the results obtained from exposing 48 plastics and elastomeric materials over a dose range of 3×10^6 r to 9×10^7 r. Spent reactor fuel elements were used as the source of gamma (ionizing) radiation. The studies were undertaken to procure practical engineering data for the design engineer.

Although all of these materials will become damaged from long exposures, plastics and elastomers can, with proper evaluation and selection, be used satisfactorily in radiation fields.

Among the materials evaluated, a styrene-butadiene rubber (PR 408-70) appeared to be the least affected. Two acrylic materials (Acrylon BA-12 and EA-5) and two vinyl chloride materials (Vyflex L-10 White and Black) appeared almost equally as good as the styrene. Teflon was the poorest of the materials, being severely damaged at 3×10^6 r. Kel-F Elastomer and a butyl type (Hycar 2202) became soft and tacky, indicating their poor suitability for use in radiation fields. The acrylics, neoprenes, nitriles, and ethylenes appeared to be about equally damaged as classes, with some overlapping with respect to the individual materials within the classes. The silicone elastomers were generally damaged more severely, although the phenyl types were affected less. Although elongation is a sensitive property and provides a fairly good index of the degradation of the materials, a study of the effects on several properties is necessary to obtain the true condition of the materials.

IEC-0358

LeClair H G and Cobbs W H, Jr.
EFFECTS OF RADIATION ON PLASTIC PACKAGING FILMS,
Industrial and Engineering Chemistry, Vol. 50, No. 3, pp. 323-326, March (1958), (20 refs).

The effects of irradiation on high polymers have been investigated in recent years. However, much of the work reported was performed on bulk samples for both irradiation and testing. In this work, polymers were irradiated and tested in the form of thin films. Although the fundamental changes should be the same regardless of the physical state of the polymer, they may be reflected differently in films because different testing methods measure different combinations of these fundamental changes. In this report are summarized the effects of high energy irradiation on a number of commercially available plastic films.

In general the physical properties of these polymers are degraded with increasing radiation exposure, regardless of whether or not the polymer is crosslinked. The amount of such degradation at any given exposure level depends markedly on the structure of the polymer.

The polyethylene, as shown by solubility measurements, is crosslinked by irradiation. At the same time it is unique in showing the sharply increased impact strength; all the other properties are degraded with increasing exposure at room temperature. Crosslinked polyethylene becomes a very viscous liquid. However, these effects impart no advantages to the film when used for normal packaging applications at room temperatures.

JPS-0258

Deeley C W, et al.
EFFECT OF PILE IRRADIATION ON THE DYNAMIC MECHANICAL PROPERTIES OF POLYETHYLENE,
Journal of Polymer Science, Vol. 28, pp. 109-120, February (1958).

The effects of pile irradiation on the damping and resonant frequency of a "high pressure" polyethylene were investigated over a temperature range from 80° to 550°K in the audio-frequency region using an apparatus which drives rod-like specimens in their transverse modes. Using irradiation dosages which result in approximately 4% crosslinking or greater, the mechanical loss peaks found at about 165°, 265°, and 355°K in polyethylene are altered. Definite changes in the resonant frequency or modulus-temperature plots also occur. The 355°K peak, attributed to the melting of the crystalline portions of the sample, decreases in height and shifts to lower temperatures with increasing irradiation dose. A decrease in the height of the 265°K peak accompanied by a shift to higher temperatures takes place. The 165°K peak initially increases in height and peak temperature, but at higher dosages a marked decrease in the damping maximum occurs. The damping behavior in the 165° and 265°K regions is discussed in terms of diffusional motion of chain segments in the amorphous polymer portions.

JPS-0358

Angier D J and Turner D T
GRAFT INTERPOLYMERS FORMED BY γ-IRRADIATION OF METHYL METHACRYLATE-NATURAL RUBBER MIXTURES,
Journal of Polymer Sciences, Vol. 28, pp. 265-274, March (1958).

On exposure to Co^{60} γ-radiation, mixtures of natural rubber and methyl methacrylate yield almost exclusively an appreciable amount of free polymethyl methacrylate which is formed only in the presence of a transfer agent or following radiation-induced degradation of the interpolymer. The influence of the purity of the rubber, monomer concentration, field intensity, the presence of transfer agent, and the gel effect on the rate of formation, yield, and structure of the interpolymer are reported.

JPS-1257-1

Bauman R and Glantz J
THE EFFECT OF COPOLYMER COMPOSITION ON RADIATION CROSSLINKING,
Journal of Polymer Science, Vol. 26, No. 114, pp. 397-399, December (1957), (1 ref).

The efficiency of radiation crosslinking as a function of copolymer composition has not been extensively studied to date. This paper presents two figures showing radiation crosslinking of butadiene-styrene and butadiene-acrylonitrile copolymers. The curves show swelling ratio as a function of weight percent for given total gamma doses.

At any given dose the crosslink density decreases with increasing styrene content. In the case of acrylonitrile copolymers the situation is more complex. Up to exposures of $3\text{-}5 \times 10^7$ roentgens, the acrylonitrile exerts a protective influence. Above this exposure, there appears to be some evidence of enhanced crosslinking with increasing acrylonitrile content. The mechanisms of these structure interactions are not understood at present.

JPS-1257-2

Glegg R E and Kertesz Z I
EFFECT OF GAMMA-RADIATION ON CELLULOSE,
Journal of Polymer Science, Vol. 26, No. 114, pp. 289-297, December (1957), (17 refs).

The present investigation arose out of studies on the effect of ionizing radiations on the texture of fruits and vegetables, in which it was shown that considerable softening of the tissues could be induced at comparatively low dosages. This phenomenon could be due, at least in part, to the degradation of the cellulose component of cell walls. A study of model systems of cellulose was therefore undertaken to determine the degradation caused by gamma radiation in the dosage range known to affect the texture of fruits and vegetables. Particular emphasis was placed on the effect of moisture content on degradation. In addition, this paper presents some further observations on the "after-effect" of gamma-radiation-induced degradation of cellulose reported previously.

KAPL-731

Mincher E L
SUMMARY OF AVAILABLE DATA ON RADIATION DAMAGE TO VARIOUS NONMETALLIC MATERIALS,
General Engineering Laboratory, General Electric Co., Schenectady, N.Y., Contract No. W-(31-109)-Eng-52, April 2, 1952, 51 pp. (71 refs).

This document abstracts from the literature the known effects on selected nonmetallic materials. The original sources are quoted, giving the doses, the physical changes noted, and the source of the radiation. The emphasis is on the electrical insulating materials. The following types of materials were studied: (1) lubricants and organic liquids, (2) plastics and elastomers, and (3) ceramic electrical insulator materials.

Conclusions concerning the lubricants and liquids were:

1. Alkyl derivatives of aromatics are the most radiation-resistant lubricants, whether or not the samples are exposed to air.
2. Ether-linked polymers are also radiation-resistant.
3. High molecular weight polymers commercially used as viscosity improvers are depolymerized by pile radiation.
4. The effects of oxidation inhibitors vary with the material.
5. An electric motor equipped with lubricated ball bearing can be operated in a pile.
6. Improved choice of lubricants now would permit the operation of a test stand engine with some qualification at low temperatures.

The plastics and elastomers studied to failure were allyl diglycol carbonate. Casein, cellulose acetate, cellulose acetate bulyrate cellulose nitrate, ethyl cellulose, fluoroethene, furfural alcohol polymer, lucite, masonite, melamine resin-glass cloth laminate, mica tape, neoprene, nylon, phenol formaldehyde with linen, cotton, paper, with asbestos bakelite polyester plastic polyethylene, polystyrene, saran, silicone resin cloth laminate silicone pasted mica tape, teflon, vinyl chloride acetate, vortex silicone-coated glass fiber.

A number of ceramics were given pile exposures. The changes in electrical resistivity and dielectric strength for the exposures are tabulated. Alumina, beryllia, sillimanite, zirconia, mica and some glass-mica mixtures were studied.

KLX-68

DETAILED PROJECT STATUS REPORT - REMOTELY OPERATED THOMPSON DISCONNECT,
The Kellex Corporation, New York, N.Y., Contract No. AT-(30-1)-Gen-169, September 26, 1949, 18 pp. (1 ref).

The main effort of this project was directed toward the development, fabrication and test of a plastic seal (gasket) for the Thompson Quick Disconnects proposed for installation in the process lines of the Job 11 Metals Recovery Plant, the main process sections of which it was proposed to install under water. This device offers particular advantages in underwater operation. Various seal materials were examined in order to obtain a seal which could be used in the device. The two most promising materials appear to be Kel-F and Teflon.

LAC-NR-51 (Vol. 3)-23

Collins C G
COMBINED TIME, TEMPERATURE, AND RADIATION EFFECTS ON ORGANIC MATERIALS,
General Electric Company, Cincinnati, Ohio. Paper presented at the 3rd Semi-Annual Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 16 pp. (5 refs).

Experimental observations of combined time, temperature, and radiation effects on a lubricating oil and Teflon aircraft engine hoses are described for the temperature range from 80° to 400°F and for radiation rates of 10^6 to 5 x 10^7 ergs $(gmC)^{-1}$ hr^{-1}.

The results show that at a constant radiation rate the failure time - as judged by the oxidation-induction period of the oil and by leaks in the Teflon hoses - follows an Arrhenius-type relationship with temperature. At a constant temperature, failure time was found to follow a logarithmic relationship with radiation dose rate. The overall results can be described in a summary equation in terms of time, absolute temperature, and radiation dose rate.

Several implications of the summary equation are discussed in reference to radiation effects in organic materials. One implication is that observations of equal damage at constant dosage irrespective of dose rate may be valid at only one temperature or at high dose rates.

LAC-NR-51(Vol. 3)-24

Gregson T C and Gehman S D
RADIATION DAMAGE OF AIRPLANE TIRE MATERIALS,
The Goodyear Tire and Rubber Company, Akron, Ohio. Paper presented at the Third Semi-Annual Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 25 pp. (20 refs).

An airplane tire is a relatively complex, highly stressed structure. Radiation damage effects are unusually complicated in this case because of the number of materials involved and the cooperative effort required of each. Damage to tire components typical of present production was studied with cobalt-60 gamma radiation. The influence of various environmental factors was also investigated. Tire fabric and fabric-rubber

adhesion are far more susceptible to radiation damage than are the rubber compounds in general use. Damage to the fabric is especially critical, in terms of tire performance, since it bears the brunt of the stresses. Cord fatigue and dynamic adhesion are the most serious aspects of radiation damage to tires. Various types of nylon tire cords possess significant differences in their ability to withstand irradiation. Presence of a nitrogen atmosphere was found to be very efficacious for reducing radiolysis in nylon cords. It was thus conceived that nitrogen inflation would provide a practical means of raising the damage threshold of tubeless airplane tires. Several nitrogen inflated tires were exposed to a dose of 10^7 rad, a level above the damage threshold for nylon cords when irradiated in air. Their performance in laboratory tests confirmed the protective benefits of nitrogen inflation.

LAC-NR-51 (Vol. 3)-27

Thomas Frank W
AIRCRAFT RADOME DESIGN PROBLEMS ASSOCIATED WITH A NUCLEAR ENVIRONMENT,
Lockheed Aircraft Corporation, Marietta, Georgia. Paper presented at the Third Semi-Annual Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 7 pp. (9 refs).

The effects of nuclear radiations in relation to microwave transmission through a dielectric lens, or radome, presents a number of design problems associated with nuclear-powered aircraft. A mathematical prediction technique was used to estimate the effect of radiation on multilayer dielectric flat panels.

The results show how radiation effects data may be interpreted in the design of a radome test panel.

LAC-NR-51 (Vol. 3)-35

Barnett D E
RADIATION TESTING OF J-79 ORGANIC ENGINEERING MATERIALS AND COMPONENTS,
General Electric Company, Cincinnati, Ohio. Paper presented at the Third Semi-Annual Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 1 p.

A number of organic engineering materials and components used by the General Electric Company on J-79 turbojet engines have been and are presently being irradiation tested at the ANPD in an effort to determine the applicability of these materials in propulsion machinery for nuclear powered flight. The materials and components are irradiated in anticipated thermal environments while being subjected to functional pressure and fluid flow. The materials and components under investigation include a turbojet lubricant, hydraulic fluid, fuel, elastomer seals, gaskets, and hoses. The elastomer materials consist of seven commercial products in the form of fabricated O-rings, gaskets and flexible hoses.

This paper will present the past, present and planned materials and components irradiation programs, post-irradiation materials evaluation, the necessity for information of this kind, and other problems and considerations associated with applications proving radiation tolerance of organic engineering materials.

LAC-NR-51 (Vol. 5)-54

Van Lint V A J and Miller P H, Jr.
ELECTRICAL EFFECTS OF HIGH-INTENSITY IONIZING RADIATION ON NONMETALS,
General Atomic Division of General Dynamics Corporation, San Diego, Calif. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 10 pp.

It is well known that nuclear radiation produces permanent damage to electronic components. This damage is associated with the displacement of atoms from their normal sites in crystals and molecules. The advent of very intense sources of ionizing radiation has introduced another problem into electronic circuitry -- the transient electrical conductivity induced in otherwise poorly conducting materials. This conductivity is due to the electron excitation produced by the ionizing radiation.

Experiments have been performed to measure the magnitude of these effects. The radiation source used was an electron linear accelerator capable of delivering dose rates in excess of 10^8 rad/sec during 10-μsec pulses. The materials which have been studied include resistors, capacitors, and semiconducting diodes.

The apparent resistance of a megohm resistor during the irradiation was less than 2×10^4 ohms. However, this effect was proved to be due primarily to the ionization of the air surrounding the component and its leads. Transient conductivity of a megohm resistor encapsulated in an evacuated container was not detectable in these experiments. However, electrical effects were observed even in this case. These effects were associated with electrons being emitted by the component and its leads during the irradiation (i.e., photoeffect).

Capacitors exhibit the same type of behavior as resistors. The data can be interpreted in terms of a mean trapping time for the carriers which are induced in the dielectric by the radiation. This trapping time in the dielectric of a mica capacitor has been shown to be less than 2×10^{-13} sec. This value indicates that the product of trap density and trap concentration is greater than 2×10^5 cm^{-1}, a quantity which is unexpectedly large.

Rectifying semiconducting junctions are affected drastically by ionizing radiation. Reverse currents as large as 100 ma can be observed during intense radiation, and pulses containing as little as 0.1 rad delivered during 10 μsec have appreciable effects (> 50 μa reverse current in a 1N91 diode).

These effects can have significant influence on circuits which may be exposed to intense ionizing radiation. Future experiments are planned to study in detail the effects in insulators and semiconductors and to evaluate quantitatively the effect of the surrounding air.

LAC-NR-51 (Vol. 5)-56

Shatzen M L
A STUDY OF RADIATION EFFECTS ON FUEL TANK SEALANTS AND BLADDER CELL MATERIAL,
Lockheed Aircraft Corporation. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 7 pp.

The effects of exposure to gamma irradiation were studied on two commercial thiokol based sealants and one high-temperature bladder cell material. Samples were tested dry in their original cured state then, after exposure to 140°F, immersed in JP-4 fuel for periods equivalent to those required to reach the three radiation doses used. After gamma irradiation at 140°F, they were immersed in JP-4 fuel to radiation doses of 9.3×10^8, 3.5×10^9, and 9.9×10^9 ergs/gm (carbon). The sealants showed about 10% degradation at the intermediate dose level and serious damage at the highest dose level. The bladder cell material apparently withstood a dose of 9.9×10^9 ergs/gm (carbon) at 140°F in JP-4 without great damage.

LAC-NR-51 (Vol. 5)-57

Chambers R H
THE EFFECT OF ELECTRON RADIATION ON THE COMPLEX DYNAMIC MODULUS OF POLYSTYRENE AND HIGH-DENSITY POLYETHYLENE,
General Atomic Division of General Dynamics Corporation, San Diego, Calif. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta,Ga., 11 pp. (10 refs).

Measurements of the elastic modulus and mechanical loss at 5 to 10 kcps were made on nonirradiated and 5-Mev-electron-irradiated specimens of polystyrene and high-density polyethylene over a temperature range from 80° to 320°K. Specimens were irradiated at liquid-nitrogen and room temperatures to doses of up to 7×10^7 rads. Considerable dependence of the modulus on irradiation temperature was noted in polyethylene. The polystyrene specimens exhibited marked modification of the internal friction spectrum under room-temperature irradiation. These changes in the dynamic modulus are discussed in terms of early-stage crosslinking mechanisms.

LAC-NR-51 (Vol. 5)-58

Warrick E L, et al.
RADIATION RESISTANT SILICONES,
Dow Corning Corporation, Midland, Mich. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 22 pp. (3 refs).

Silicones as a class cover a wide range of polymer compositions within which are newer materials of outstanding radiation resistance. These take the form of fluids, greases, resins and rubbers. Inherently, silicones are thermally stable and this is reflected in excellent performance for some polymers in the combined environments of radiation and high temperature. Comments in the literature which classify silicones as poor in radiation resistance are based on observations covering only a limited area of the total field with concentration on a few of the less stable polymers.

LAC-NR-51 (Vol. 5)-59 FZM-1157

Albrecht T W
RADIATION EFFECTS ON ORGANO-SILICONS,
Convair, A Division of General Dynamics Corporation, Fort Worth, Tex. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 10 pp.

The paper discusses the heat, radiation, and oxidative stability of silicon materials. A stepwise energy reduction mechanism for oxygen is proposed that allows molecular oxygen to be changed to atomic oxygen in 30-40 Kcal increments rather than in steps of 96 Kcal. The mechanism helps explain the relative ease of oxidation of silicon materials and the products formed at relatively low temperatures.

LAC-NR-51 (Vol.5)-60

Wall Leo A, et al.
RADIATION CHEMISTRY OF FLUOROCARBON POLYMERS AND MONOMERS,
National Bureau of Standards, Washington 25, D.C. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 25 pp. (16 refs).

The changes in polymers irradiated with Co^{60} gamma rays were studied with reference to formation of gas molecules, crosslinking, and scission in air and in vacuum, as evidenced by mechanical properties such as "zero-strength-time" and free-radical accumulation and disappearance as shown by electron spin resonance. The polymers studied were: Teflon, Teflon 100X, Kel F, Kel F elastomer, Viton A, and trifluoroethylene. These polymers show great differences in radiation stability depending upon environment and constitution. The molecule hexafluorobenzene showed outstanding radiation stability, approximately comparable to benzene, and would be a promising basis for the preparation of resistant polymers. Mixtures with added hydrocarbon materials were somewhat less stable. It appears that radicals in Teflon build up approximately linearly, at least up to a dose of 72 megr, and disappear very slowly in vacuum, while in a perfluoropropene-tetrafluoroethylene copolymer the radical concentration shows signs of leveling off at 50 megr and probably declines somewhat in two days.

LAC-NR-51 (Vol. 5)-62

DeZeih Chester J
EFFECTS OF NUCLEAR RADIATION ON CORK, LEATHER, AND ELASTOMERS,
Boeing Aircraft Company, Seattle 24, Wash. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 23 pp.

Samples of cork, leather, and various elastomers were irradiated in the cobalt 60 gamma source of the California Research Corporation at dosages of ca. 10^7 to 10^{10} ergs/gram.

No significant changes were observed for cork. Tensile strength of leather was affected; no hardening was noticed. These materials can be used in certain systems in nuclear environments. Elastomers SE-551 and SE-371 are affected by nuclear radiation. At ca. 10^{10} ergs tensile strength and elongation properties decrease considerably, while hardness increases to the point of crumbling. High temperature Thiokol exhibits good properties after irradiation.

Viton A retains usable tensile strength up to ca. 10^{10} ergs, with some increase in hardness. At ca. 10^{10} ergs the percent of elongation of Viton A drops considerably.

Viton A and high temperature Thiokol appear to be promising materials for use in nuclear environments. Additional work is being planned.

LAC-NR-51 (Vol. 5)-64

Kerlin E E
'O' RING TESTING IN A MIXED FIELD IRRADIATION,
Convair, A Division of General Dynamics Corporation, Fort Worth, Tex. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 1 p.

This report describes work directed toward the development of 'O' rings that are resistant to the combined effects of radiation, fluid, temperature and pressure. This work is in two parts, screening of existing compounds, and actuator seal tests.

In the screening tests aircraft 'O' ring compounds were compared to control samples to determine the percent damage.

For the actuator seal tests, equipment was built to simulate 'O' ring seal conditions. This equipment gives information on the sealing ability of 'O' rings in actual working conditions.

Compounds that were least affected in the screening test were tested in the actuator seal test. The most promising material tested was Parco 363, a neoprene WT rubber.

Present work on this program is being directed toward development of testing techniques to give a more accurate environment for the screening tests. In addition testing will be done in the development of a more radiation resistant 'O' ring.

LAC-NR-51 (Vol. 5)-65 FZM-1156

Newell D M
RADIATION EFFECTS ON 23 SILICONE RUBBERS AT AMBIENT TEMPERATURE,
Convair, A Division of General Dynamics Corporation, Fort Worth, Tex. Paper presented at the Third Semi-Annual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 39 pp. (4 refs).

Convair-Fort Worth has conducted screening tests on 23 silicone rubbers, irradiated at three temperatures and four fluxes. The Ground Test Reactor was used. The information obtained to date is from tests conducted during February and March 1957 (MCI-4). Standard physical tests were performed.

The materials were obtained from Dow Corning, General Electric, and Union Carbide. The materials found to be the most radiation resistant were: Silastic 7-170, SE 381, Silastics 2048 and 80, and 81641 (GE). There was a definite correlation between the filler content and the damage, with the percent damage varying inversely with the percent filler.

MDDC-962

Allen A O
EFFECTS OF RADIATION ON MATERIALS,
Lecture-Seminar in Nuclear Science and Engineering, Massachusetts Institute of Technology, May 20, 1947, 17 pp. (16 refs).

This paper is a qualitative survey of the complicated subject - Effects of Radiation on Materials. High energy radiations have long been known to produce changes in chemical constitution and physical properties in the materials which they traverse. Types of radiation and their interactions with matter, effects of radiation on the different types of chemical bonds, effects of radiation on simple gases, and organic compounds are discussed.

MP-1057-1

Colichman E L and Strong J D
EFFECT OF GAMMA RADIATION ON EPOXY PLASTICS,
Modern Plastics, Vol. 35.1, No. 2, pp. 180, 182, 184, 186, 282, October (1957).

The extent to which typical thermally cured epoxy plastics might be improved by radiation postcuring has been investigated. Nine different epoxy compositions were studied containing various curing agents and the presence or absence of reactive diluents. Gamma radiation dosages were 10^6, 10^7, and 10^8 roentgens. Physical properties measured on irradiated and unirradiated specimens were hardness, heat distortion temperatures, and compressive strengths. Hardness properties were found to change the greatest amount. Hardness results can be correlated with the molecular structure of the epoxy compositions and can be used as a measure of radiation resistance. Epoxy plastics are highly radiation resistant and little change occurs in hardness on radiation when relatively inert aromatic-type curing agents are used. Active methylene groups permit cross-linking analogous to that occurring in polyethylene, and hardness increases in excess of 50% were obtained in these epoxy compositions at gamma dosages of 10^8 roentgens. If reactive groups are present that allow radiation-promoted vinyl polymerization to occur, the concentration of these reactive diluents determines whether hardness increases or decreases as a result of radiation.

Heat distortion temperatures and compressive properties are little changed by radiation up to at least 10^8 roentgens. Specific epoxy compositions show increases in compression strength of about 7%.

Radiation curing of epoxy resins to form rigid plastics without using heat is possible with compositions that permit vinyl polymerization. Radiation curing alone apparently results in a smaller and less desirable polymer molecule, due probably to the fact that the curing agents cause polymerization normally by condensation reactions which are not radiation promoted.

N-0458-1

Metz Donald J
GRAFT COPOLYMERS - A NEW TECHNOLOGY?
Nucleonics, Vol. 16, No. 4, pp. 73-77, April (1957) (11 refs).

Several promising new materials can be made by graft copolymerization. Most prominent among them are ion-exchange membranes made by grafting styrene onto polyethylene and sulfonating the styrene. An addition of properties occurs. Polyethylene has good tensile strength and flexibility, and it can be extruded or rolled into thin sheets. Polystyrene, on the other hand, is brittle but can be sulfonated to make an ion-exchange medium. Grafting makes a strong, flexible membrane that can be sulfonated.

Existing data are not sufficient to determine the effects of various experimental parameters on this process. Polyethylene films were soaked in benzene at room temperature and dried until their weight remained constant. Then they were covered with styrene monomer and exposed to Co^{60} gamma rays. Nitrogen was used to purge oxygen from a closed system. After irradiation the films were extracted with benzene and dried. Figures are included which show properties of cation exchange membranes made by sulfonating such films and, for comparison, those of several currently marketed membranes.

Anion-exchange membranes can be made by grafting vinyl pyridine to polyethylene and following with quaternization or by introducing quaternary amine groups into the styrene-polyethylene copolymers. Their properties are similar to the cation-exchange membranes just described.

N-0558

Artandi Charles and Stonehill A A
POLYVINYL CHLORIDE - NEW HIGH-LEVEL DOSIMETER,
Nucleonics, Vol. 16, No. 5, pp. 118-120, May (1958), (11 refs).

This paper discusses polyvinyl-chloride film which has been found to be a good dosimeter for electron doses in the 0.5-6 megarad range. It turns amber in color and a measurement of optical density indicates the absorbed dose within ~8%. The film makes a cheap, simple, accurate and permanent dosimeter. After proper standardization it is equally good for gamma-ray dose. The mechanism of discoloration of irradiated high polymers is discussed and compared to that of irradiated glass.

Other known dosimeters in the megarep range are discussed. These are silver-activated phosphate glass, photographic print-out paper, and a pH-sensitive dye into polyvinyl-chloride film.

NAA-SR-158

Rasor N S and Nading J M
RADIATION AND HEAT RESISTANT VACUUM SEALS,
North American Aviation, Inc., Downey, Calif., Contract No. AT(11-1)-Gen-8, December 18, 1951, 28 pp. (6 refs).

A vacuum seal utilizing an inflatable sheet metal gasket has been developed for applications in which high intensity nuclear radiation or high temperature make the use of conventional sealing materials and techniques unsatisfactory. A test model of this seal is described and a possible mechanism to explain its observed performance is proposed. The application of this seal and its modifications is discussed with a view toward its suitability for use in the MTA Mark III accelerator. Alternative seals also considered include a gasket of an alloy of gold and cadmium having unusual elastic properties, and a multiple pump-out arrangement employing no gasket.

NARF-56-27T-5 MR-N-122-5 X-21883

PROCEDURES FOR SYSTEM PANELS TEST NO. 2, ADDENDUM 5,
Convair, A Division of General Dynamics Corp., Fort Worth, Tex.,
Contract No. AF33(600)-32054, September 7, 1956, 47 pp.

System Panels Irradiation Test No. 2 has been performed at Convair-Fort Worth during late 1956 and early 1957. In this test, existing aircraft systems mounted on test panels were irradiated, using the Ground Test Reactor as the source. The Ground Test Reactor was placed in the dry pool, and the panels to be irradiated were grouped around the reactor inside the pool. Measurements were made of thephysical properties and operating characteristics of the panel before, during, and after irradiation.

This report is the fifth addendum to Procedures for System Panels Test No. 2 (Convair-Fort Worth Report MR-N-122). It describes the static systems to be irradiated and tested. It also establishes procedures for the exposure, testing, and handling of this equipment. Essentially this equipment consists of a disc-type Rotor Brake, Tire and Tube Assembly and Chaff Samples supplied by Wright Air Development Center, Dayton, Ohio; Type 9519 Liquid Spring Shock Struts supplied by Cleveland Pneumatic Tool Co., Cleveland, Ohio; and Plastic Laminate Coupons supplied by Zenith Aircraft, Gardena, California.

Other static systems to be irradiated in this test but not described in this series of addenda are: Aluminum Structural Materials and Fuel Bladder supplied by Lockheed Aircraft Co., Marietta, Ga.; various material samples supplied by Glenn L. Martin Aircraft Co., Baltimore, Md.; Elastomers and Sealants supplied by Test Laboratory, Convair-Fort Worth, Texas; and various oil samples supplied by Wright Air Development Center, Dayton, Ohio; Shell Development, Emeryville, California; California Research Corp., Richmond, California.

Although the above samples are not covered by Planning Documents, the complete results will be published in the final report.

NARF-57-19T(Vol. 4)-3 X-21783

Griffin W R
RUBBER IN A NUCLEAR ENVIRONMENT,
Wright Air Development Center, Wright-Patterson AFB, Ohio. Paper presented at the First Semi-Annual 125A Radiation Effects Symposium, May 22-23, 1957, Convair, Fort Worth, Tex., 3 pp.

We find rubber among those materials most sensitive to nuclear radiations. Since it appears that rubber will be a necessary part of this nuclear system, the limitations as a material must be established.

The B. F. Goodrich Company has been under Air Force contract for approximately 3-1/2 years to study all phases of radiation damage. The results of this work which have been published in three summary reports are briefly discussed.

In addition, work at WADC has been directed toward high temperature and simulated testing of new fluid resistant elastomers. Results of this work which will also be published soon, is briefly covered.

Supporting work of direct interest is being conducted at Oak Ridge National Laboratory, who are providing fundamental data using mixed radiations.

The air frame and engine manufacturers are assisting with this project by establishing the limitations on commercial materials.

NARF-57-54T MR-N-174

Johnson R E and Sicilio F
RADIATION DAMAGE TO ELASTOMERS AND SEALANTS --I,
Convair, Fort Worth, Tex., Contract No. AF-33(600)-32054, November 26, 1957.

Elastomer and sealant samples were irradiated in air and some sealant samples were irradiated while immersed in Type III hydrocarbon fuel. The samples irradiated in air received an average integrated fast neutron flux of 6×10^{14} nvt and an average integrated thermal neutron flux of 6×10^{13} nvt.

NARF-58-1T (Add. 5) FZK-9-126-5

RESULTS OF SYSTEM PANELS TEST NUMBER 2 - ADDENDUM 5,
Convair, A Division of General Dynamics Corporation, Fort Worth, Texas, Contract No. AF-33(600)-32054, September 6, 1958, 177 pp.

This report discusses eight tests performed at Convair-Fort Worth during late 1956 and early 1957.

Reinforced plastic laminates were tested. As a result some characteristics improved, some remained constant and others were harmed by the mixed flux environment of gamma (20×10^6 roentgens) and neutron radiation (3.5×10^{14} nvt). No changes were observed in the resin content or the specific gravity. Polyester laminates and silicon laminates were tested and compared at 450°F, 500°F, and room temperature.

Three jet fuels irradiated underwent small changes in composition commensurate with total dose but a major decrease in thermal stability. The degrading effect of the combined neutron-gamma flux appears to be mainly due to the gamma flux level and possibly to solution of iron.

A wide variety of synthetic oils (esters, hydrocarbons, silicones, etc.) were irradiated to determine their sensitivity to reactor radiation. The total absorbed radiation, approximately equivalent to 6×10^6 rad, was low and caused no significant property changes in most of the materials. Inhibited ester oils that contained tricresyl phosphate did show appreciable loss of antioxidant activity and increased considerably in high-temperature deposit forming tendencies. Similar changes in tricresyl phosphate containing ester oils were observed after irradiation to the same level with cobalt-60 γ-rays. Reactor irradiations to much higher levels will be needed before any possible neutron sensitivities of the more stable oils can be determined.

A limited experimental investigation into the effects of nuclear radiation on the tear resistance characteristics of 2024-T81 and 7075-T6 clad aluminum sheet and Type 422 CRES sheet was conducted. Irradiated and nonirradiated specimens were compared on the basis of the ultimate gross stress, F_g, and the nondimensional ratio of crack length at maximum load to panel width, X_{ml}/B. Only representative examples of crack growth versus load curves for each of the materials are presented in this report. Complete data may be found in Reference 11. The low level irradiation had no detectable effect upon the tear resistance of these materials.

Two standard and three experimental types of chaff were irradiated. These samples received a total gamma dose of 2.0×10^7 R, and a total flux of 2×10^{14} nvt. There was

no noticeable radiation damage to the chaff itself. However, the rubber cement holding the rayon reinforcing fibers in the puller tapes deteriorated, leaving the tapes stiff and brittle resulting in doubtful serviceability of the chaff units.

A Bendix aircraft brake assembly was irradiated statically. The test was conducted at Convair-Fort Worth with the Ground Test Reactor (GTR) as the radiation source. The assembly was exposed to an average integrated neutron flux of 5.5×10^{14} n/cm^2 and a gamma dose of 6×10^6 R. No radiation damage was detected after this exposure.

Two oils and one fuel supplied by California Research Corporation were irradiated. The oil and fuel samples were subjected to an integrated neutron flux of 1.2×10^{14} n/cm^2 and a gamma dose of 1×10^7 R. The test results indicate that the physical properties of the oils were changed only slightly but that the oxidation-corrosion performance was adversely affected. An adverse effect was also experienced on the coking properties of the fuel.

A selection of sealants, elastomeric samples, fabrics, plastics, wire insulation, finishes, bonded metals, and thermal insulation material along with corrosion test samples and a simulated seaplane hull bottom were irradiated statically. The test samples were irradiated to an average integrated neutron flux of 2.4×10^{15} n/cm^2 and gamma dose of 1.5×10^8 R. Radiation damage was detected in the sealants, elastomeric materials, fabrics, and wire insulation.

NARF-58-5T

Johnson R E and Sicilio F
RADIATION DAMAGE TO PLASTICS AND COATED FABRICS - 1,
Convair, A Division of General Dynamics, Fort Worth, Tex., Contract No. AF-33(600)-32054, January 24, 1958, 55 pp. (34 refs).

Various plastics, plastic laminates, fabric laminates, glass cloth laminates and a fabric were irradiated in October 1955 using the Ground Test Reactor at Convair-Fort Worth. The specimens were subjected to an average integrated fast-neutron flux of 6×10^{14} nvt, an average integrated thermal-neutron flux of 6×10^{13} nvt, and an average integrated gamma flux of 5×10^{16} gammas/cm^2.

After irradiation, tests were performed on irradiated and control samples to detect changes in physical properties resulting from the irradiation. The properties which showed most change were tensile strength, elongation, compressive and flexural strength, hardness, and tear strength. However, a trend in the changes was not discernible; for example, in some cases tensile strength was increased, and in samples of the same type materials, a decrease was noted. The samples displayed few changes in thermal expansion, dielectric constant, surface resistivity, and loss tangent.

NARF-58-10T MR-N-190

Albrecht T W
RADIATION EFFECTS ON ORGANO-SILICONS,
Engineering Department, Convair, A Division of General Dynamics Corporation, Fort Worth, Tex., Contract No. AF-33(600)-32054, February 25, 1958, 52 pp. (27 refs).

The paper discusses the heat, radiation, and oxidative stability of silicon materials. A study is made of the comparative stability of silicon with organic molecules through the

use of electronegativity and bond strength differences of the elements and the rate of diffusion of the free radicals away from their bond rupture site.

A stepwise energy reduction mechanism for oxygen is proposed that allows molecular oxygen to be changed to atomic oxygen in small 30-40 Kcal increments rather than in one big step of 96 Kcal. The mechanism helps explain the relative ease of oxidation of silicon materials and the products formed at relatively low temperatures. Theories of antioxidants as a means of protecting irradiated silicon materials are discussed briefly.

When the structure of a silicon compound is known, its thermal and/or radiation stability can be estimated. Traces of impurities (metals, H*, OH) mixed with the silicon materials can favor undesirable catalytic reactions that are capable of rendering the material useless when exposed to radiation and/or thermal environments. A mechanism has been proposed in which oxygen has been considered to break down in 30-40 Kcal/mole increments in its change from molecular oxygen to atomic oxygen. Thus, oxidation of the silicon can take place at lower temperatures than if 96 Kcal/mole were required as is often reported in the literature. Antioxidants act as either an oxygen or a free radical scavenger, thereby hindering crosslinking of the main chains.

NARF-58-51T MR-N-174-2

Newell D M
THE EFFECTS OF REACTOR RADIATION ON ELASTOMERS AND SEALANTS - II,
Convair, A Division of General Dynamics Corp., Fort Worth, Tex.,
Contract No. AF-33(600)-32054, December 29, 1958, 28 pp. (2 refs).

Fifteen elastomers - one fluorinated, one natural, one nitrile, and 12 silicone rubbers - were irradiated to maximum integrated fluxes of 4.5×10^{14} n/cm^2 (fast neutrons) and 1.2×10^9 ergs/cm(C)(gamma). Standard physical property tests were made after irradiation.

Twelve of the rubbers were screened at the maximum flux, and all were found to be damaged in at least one property; the General Electric SE-750 was found to be least affected. In a threshold study of three of the elastomers, curves were obtained showing the damage trends.

NAVR-SYM-ACR-2 (2)

Crecelius S B
A SURVEY OF THE CHEMISTRY OF POLYMER FORMATION,
Naval Research Laboratory, Washington, D.C. Paper given at Conference on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 8 pp. (3 refs).

In this paper an attempt is made only to cover the general reactions relating to some of the most common types of polymers in order that a relation may be established between these reactions and the behavior of these materials when treated with radioactive irradiation.

These reactions may be divided roughly into several types; namely, that of condensation, free radical polymerization, esterification, etherification and combinations of these.

NAVR-SYM-ACR-2 (3)

Callinan T D
POLYMER SYNTHESIS BY GAMMA RADIATION,
Naval Research Laboratory, Washington, D. C. Paper given at Conference on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 6 pp.

This paper covers the experimental use of Co^{60} gamma rays in performing the function of radiation catalyst in each of three compounds: (1) ethylene derivatives, (2) polyesters and (3) polysiloxanes.

NAVR-SYM-ACR-2 (14)

Sisman O and Bopp C D
RADIATION STABILITY OF POLYMERS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper given at Converence on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D. C. December 14-15, 1954, 7 pp.

The ultimate result of the reaction of high-energy radiation with organic polymers is primarily to cause crosslinking and chain cleavage. Except for very hard materials, the effect of displacements due to collisions of nuclei with heavy particles is small compared to the crosslinking and chain cleavage caused by ionization, and may be neglected.

To have a radiation resistant polymer the material must (1) be able to absorb energy with a minimum amount of ionization, and (2) the reaction should be predominantly crosslinking rather than chain cleavage. In addition to this the changes will be slower if the material is rigid.

NAVR-SYM-ACR-2 (15)

Meyer R A
CONDUCTIVITY OF POLYETHYLENE AND TEFLON DURING IRRADIATION AT LOW TEMPERATURE,
Naval Radiological Defense Laboratory, San Francisco, Calif. Paper given at Conference on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 4 pp. (3 refs).

For a number of years it has been known that the electrical conductivity of plastic insulators greatly increases over its initial value when measurements are made immediately after the sample has been irradiated.[1] Other investigators have noted that this change is temperature dependent and does not vary with the type of material being irradiated.[2] Although the increased conductivity has been measured, the cause for such a change has not been determined; that is, whether the charge carriers are electrons or ions. This investigation has been undertaken to attempt to determine experimentally whether the conductivity change is dependent on the type of material being irradiated, total dose, or flux and finally, if the charge carriers are electrons or ions.

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[1] F. T. Farmer, Nature 150:521 (1942).

[2] S. Mayburg, "Conductivity in Good Insulators During Gamma Irradiation," WAPD-RM-122.

It was assumed that hydrogen ions would be present in polyethylene due to irradiation if any ions existed. A recent article indicates that this assumption is correct.[3] Likewise, it seems reasonable that fluorine ions will be produced in Teflon if it is irradiated and this ion will have a lower mobility than the hydrogen ion. If the charge carriers are ions, the change in conductivity for polyethylene and Teflon should be different if the samples are irradiated at low temperatures.

Conductivity measurements were made before, during, and after irradiation of the sample. The sources employed in this study were cobalt-60 and gammas from a gold target bombarded by electrons from a Van de Graaff generator. The flux intensities from the cobalt source were approximately 20 r/min and 423 r/min. Those from the gold target were varied from 30 r/min to 1223 r/min, depending upon the number of electrons striking the gold target. These fluxes were determined with a rate meter and phosphate glass dosimeters.

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[3]M. Dole, C. K. Keeling, and D. G. Rose, J. Am. Chem. Soc., 76:4304 (1954).

NAVR-SYM-ACR-2 (17)

Sun K H
EFFECTS OF ATOMIC RADIATION ON HIGH POLYMERS,
Westinghouse Electric Corporation, East Pittsburgh, Pa. Paper given at Conference on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 30 pp. (217 refs).

When atomic radiation passes through ordinary matter, the energy is dissipated largely through ionization and electronic excitation, plus a small fraction through atomic displacement and lattice disturbance, and usually an even smaller fraction through transmutation. For different kinds of radiation and different kinds of matter, the effects differ primarily in degree rather than in kind.

Since high polymers are covalent substances, the effect of radiation is largely caused by ionization and electronic excitation. These processes cause instantaneous flow of electric current and the breakage and rearrangement of chemical bonds, and the formation of free radicals. Consequently, chemical reactions are initiated. The phenomenological results include gas liberation, double-bond formation and elimination, degradation, polymerization, crosslinking and vulcanization, vitrification, hydrogenation, and others. As a consequence, many important physical properties are changed.

The implications of atomic radiation are far reaching in their practical respect. Understanding of the deleterious effects has already resulted in development of high polymers that will withstand intense radiation. Studies of beneficial effects indicate that atomic radiation provides to the scientific and technical world a new experimental variable or tool unique in itself. Already, high polymers of better physical or chemical properties are produced that cannot be achieved otherwise.

NAVR-SYM-ACR-2 (19)

Wall L A
ATOMIC RADIATION AND POLYMERS,
National Bureau of Standards, Washington, D. C. Paper given at Conference on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D. C., December 14-15, 1954, 10 pp. (19 refs).

The behavior of polymers when exposed to high-energy radiation is reviewed and discussed. Data on heats of polymerization, which reflect steric hindrance, thermal decomposition, and bond energies are used for the purpose of elucidating the factors involved in the crosslinking or degradation of polymers when irradiated. A mechanism involving the random formation of radicals followed by the characteristic reactions of such species appears to be a possible explanation of the observed changes in polymers.

In addition, some evidence is offered for the existence of immobilized radicals in irradiated polymethyl methacrylate.

65

NAVR-SYM-ACR-2(20)

Saldick J
ANALYTICAL EVALUATION OF THE EFFECTS OF RADIATION ON ORGANIC MATERIALS, General Electric Co., Cincinnati, Ohio. Paper given at Conference on Effects of Radiation on Dielectric Materials, Naval Research Laboratory, Washington, D.C., December 14-15, 1954, 5 pp. (1 ref).

Practical questions, which design engineers ask about the effects of radiation on specific materials, usually cannot be answered completely enough from our meager understanding of the basic principles of the effects of radiation on matter. Yet extensive programs of engineering testing are exceedingly costly and must be avoided, if possible. Many times, the necessary information can be derived from data in the literature by using the proper procedures for applying it to a problem at hand. This paper attempts to show possible procedures for deriving engineering effects analysis from basic principles of radiation effects on matter.

NBS-5903

Wolock Irvin and Parker Midgetts
INVESTIGATION OF THE EFFECTS OF NUCLEAR RADIATION ON THE PROPERTIES OF TRANSPARENT PLASTICS, S57-55,
Organic and Fibrous Materials Division, National Bureau of Standards, May 22, 1958, 20 pp. (7 refs).

Copolymers of methyl methacrylate and of styrene were polymerized and irradiated in an effort to produce a transparent plastic of improved heat resistance for use as aircraft glazing. It was also desirable that the copolymer have good weathering properties.

Comonomers selected for study were as follows: (1) those reported as crosslinking readily when irradiated, (2) those having excellent weathering stability, and (3) those selected to check some of the results and theories reported in the literature. The comonomers investigated were ethyl methacrylate, octyl methacrylate, methyl acrylate, isobutyl acrylate, actyl acrylate, methyl alpha-chloroacrylate, vinyl acetate, allyl acetate, acrylonitrile, 2, 5-dichlorostyrene, and 1, 3-butadiene. Copolymers prepared from these comonomers were irradiated in a cobalt-60 source for dosages up to 100 megaroentgens in most cases. Properties used to evaluate the results of irradiation were precipitation titration, intrinsic viscosity, swelling and heat deformation. In general, the results indicate that if a copolymer is prepared with a major percentage of a comonomer known to produce a homopolymer that crosslinks, the copolymer will crosslink, and vice versa. It was also found that thermoplastics can be crosslinked without increasing their deformation temperature appreciably.

Butadiene or acrylonitrile copolymerized with methyl methacrylate and acrylonitrile copolymerized with styrene appear to be the most promising for further study as possible aircraft glazing materials.

NP-5218

FINAL SUMMARIZING REPORT - RADIATION DAMAGE STUDY - EFFECTS OF IONIZING RADIATION ON CERTAIN MATERIALS,
The Sarah Mellon Scaife Radiation Laboratory, University of Pittsburgh, Pittsburgh, Pa., Contract No. DA18-108-CML-3429, March (1954), 50 pp. (32 refs).

The expanding uses of atomic energy make it necessary to study the effects that gamma rays and high energy particles have on materials that are used in a strong irradiation field.

This report covers studies which have been made of the effects of radiation on silicone rubbers, silicone polymers, O-rings, refrigerants, chemical compounds, grease and oils in order to determine their usefulness after exposure to high intensity gamma-ray flux. The chemical compounds investigated included: Tantalum and lead oxide tested for mechanical properties; potassium silicate and zinc chloride for their deliquescence; hercolyn, staybelite, silicone oil, abalyn silastic and abitol tested for thickness; and fluoro-chemicals, calcium hydride, calcium nitride, and potassium phosphate tested for off-gassing during irradiation.

NP-6097

Kinderman E M and Radding S B
LITERATURE SURVEY OF RADIATION OF ADHESIVES AND RELATED MATERIALS, Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio, June 15, 1956, 73 pp. (187 refs).

A review of the literature about the radiation effects on commercially available adhesives and plastics. Two categories are covered by this bibliography: polymerization by irradiation and irradiation of polymers. Each category is covered as follows:

A. General
B. Thermosetting materials
C. Thermoplastic materials
D. Elastomers
E. Adhesives
F. Miscellaneous materials

Definite emphasis is placed on the formation, improvement, and degradation of polyethylene by irradiation.

NP-6430

THE EFFECT OF NUCLEAR RADIATION ON STRUCTURAL ADHESIVES AND PLASTICS, Bimonthly Report No. 1, June 7, 1957 to August 15, 1957, Stanford Research Institute, Menlo Park, Calif., Contract No. AF-33(616)-5369, August 15, 1957, 7 pp. (1 ref).

This document indicates some of the work being done on laminating resins and lap shear specimens. This work is incomplete and later publications should be consulted.

The antirad and scintillator work indicate that 2.5-phenyloxayole is the best protector found to date for the organic components of adhesives.

NRL-4938

Duffey Dick
THE IRRADIATION OF POLYVINYL METHYL ETHER WITH ELECTRONS AND GAMMA RAYS TO FORM ELASTOMERS,
Dielectrics Branch, Solid State Division, Naval Research Laboratory, Washington, D.C., August 19, 1957, 33 pp. (26 refs).

Polyvinyl methyl ether and mixtures of this ether with a variety of powdered fillers were irradiated with electrons from a Van de Graaff and gamma rays from cobalt-60 to form elastomers. The fillers included carbon black, magnesia, silica, iron oxide, calcium phosphate, calcium carbonate, clay, zinc oxide, rutile, chromium sesquioxide, litharge, antimony tri-sulfide, zinc sulfide, barytes, zircon, calcium fluoride, antimony tri-oxide, zinc borate.

The ether crosslinked; however, fillers were necessary to give products with much strength. Carbon black, magnesia, silica, iron oxide, and calcium phosphate resulted in significant reinforcement. Ordinary chemical methods of crosslinking, or vulcanization, were ineffective.

The optimum amount of fillers for strength was about 30% of the mixture by volume, and the required radiation levels were the order of 40 megaroentgens. Tensile strengths of over 1500 psi with elongations at breaking of 100 to 200% were obtained. The products swelled in the solvents of the crude ether. In particular, cold water swelled the products, which could be a serious limitation to many uses. Some liquids, such as straight chain hydrocarbon and caustic solution, did not effect the product appreciably.

NYO-7292

Truell Rohn
RADIATION DAMAGE IN SOLIDS AS OBSERVED BY ULTRASONIC ATTENUATION AND VELOCITY MEASUREMENTS,
Brown University, Providence, Rhode Island, Contract No. AT-(30-1)-1772, January (1956), 28 pp.

Measurement of ultrasonic wave velocity and attenuation in solids yield considerable information about elastic constants, dislocation damping, and other important properties of solids. Such measurements have been made on silicon, before and after reactor irradiation, and on alkali halides before, during, and after exposure in intense gamma-ray sources. Results of irradiating other materials with gamma rays are mentioned briefly. Reactor irradiation increases the attenuation in silicon but this increase gradually disappears in about one year, when the sample stands at room temperature.

The effects of reactor radiation on silicon appear to be connected with dislocation damping. It is not yet clear that the effect of intense gamma-ray irradiation of alkali halides is connected with dislocation damping; there may be electrical damping effects

observed by ultrasonic attenuation. The effect of cold working on changes in attenuation caused by gamma radiation in alkali halides is not yet settled although it seems clear that there are effects of this type.

NYO-7499

Sauer J A
EFFECT OF RADIATION ON DYNAMIC PROPERTIES OF HIGH POLYMERS,
Physics Dept., The Pennsylvania State University, University Park, Pa., Contract No. AT(30-1)-1858, July 1, 1958, 19 pp.

Progress made on research work during the last year is briefly summarized. Nine additional technical papers on various aspects of this research work have appeared in print during the last twelve months and these are listed by title and author. A number of additional polymers have been investigated during the year by both dynamic mechanical techniques and nuclear magnetic resonance techniques. Studies on irradiated polyethylenes have been made both for materials subject to Co^{60} radiation as well as to pile radiation. Apparatus for measuring specific volume from 150°K to above the melting point has been completed and a series of branched and irradiated polyethylenes have been investigated. Progress has also been made in designing and constructing new apparatus for measurement of mechanical properties over a frequency range from 1/100 c/s to 20 Mc/s. Dielectric apparatus has been assembled and investigations begun, both experimental and theoretical, on determination of the detailed structure of polymer molecules.

ORNL-928

Sisman O and Bopp C D
PHYSICAL PROPERTIES OF IRRADIATED PLASTICS,
Reactor Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 29, 1951, 224 pp.

A series of graphs and charts are presented depicting quantitatively the changes in physical properties which various plastics undergo when subjected to radiation in the ORNL Reactor. Tests were made of the following properties: tensile properties, shear strength, impact strength, Rockwell hardness, change in weight, specific gravity, water absorption, light transmission and haze, volume resistivity, dielectric strength, and arc resistance.

Certain mineral-filled phenolics and styrene polymers withstood a dose of 10^{19} nvt with little change in properties. Cellulosic, casein, acrylic, and chlorofluoroethylene plastics decrease 50% in tensile strength at 10^{17} nvt. Plastics of intermediate resistance in order of resistance are: polyvinyl carbazole, aniline formaldehyde, polyethylene, nylon, polyester, organic-filled phenolic, melamine, urea, unfilled phenolics, polyvinyl-vinylidene chloride, and polyvinyl chloride acetate.

ORNL-1325

Higgins I R
RADIATION DAMAGE TO ORGANIC ION-EXCHANGE MATERIALS,
Chemical Technology Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, March 16, 1953, 13 pp. (6 refs).

The stability of polystyrene and phenolic ion-exchange resins to radiation from a Co^{60} source and from absorbed Ce^{144}-Pr^{144} was investigated. Sulfonated polystyrene cation-exchange resins lost 10 to 20% of their capacity per watt-hour of radiation absorbed per gram of oven-dry resin, while the quaternary amine anion-exchange polystyrene resins lost about 40%. Phenolic cation-exchange resins lost only 1%.

ORNL-1373

Bopp C D and Sisman O
RADIATION STABILITY OF PLASTICS AND ELASTOMERS,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, July 23, 1953, 81 pp.

Radiation-induced changes in the physical properties of several plastics that were not included in ORNL-928 and the radiation-induced changes in the commercial elastomers are reported. In addition, a number of fabrics and some specially prepared materials are examined.

For the most part, reactor radiation was used, but other types of radiation are compared with reactor radiation in producing changes in the properties of the materials studied. The effect of the presence of oxygen during irradiation and the effect of time of aging subsequent to irradiation are also studied. The rate of gas evolution and the rate of change in volume are given for many of the materials studied, and a correlation is drawn with the chemical structure. Also, changes in the mechanical properties of the polymers are correlated with their chemical structure.

ORNL-2508

Hoiberg Arnold J, Watson C D and West G A
AN EVALUATION OF ASPHALT AND OTHER MATERIALS FOR LINING RADIOCHEMICAL WASTE STORAGE BASINS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, September 10, 1958, 50 pp. (21 refs).

Asphaltic membranes appear practical for lining earth storage pits for aqueous radiochemical waste provided that the wastes are neutralized and are decayed sufficiently that the self-heating temperature does not exceed 150°F and the time for the asphalt to acquire a dose of 10^9 r is more than 25 years. In laboratory tests gamma irradiation of asphalts caused: (a) evolution of H_2 and CO_2, resulting in 14 to 30% volume increase and a honeycomb structure; (b) increase in softening point, slight increase in ductility, and decrease in penetration; (c) decrease in flash point but no increase in "loss on heating"; (d) increase in asphaltenes and resins and decrease in oils. The addition of mineral fillers was not beneficial. Prefabricated asphaltic membrane and plank samples were still serviceable after 10^9 r irradiation. Irradiated tars showed some change in ductility but little change in other physical properties.

In 1- to 4-week immersion tests, asphalts deteriorated in simulated acid waste solutions above 150°C, but changes were slight when the HNO_3 concentration was $< 1\%$. Chemical damage to tars appeared to be similar to that of asphalts but the physical changes were not actually measured.

In 1-year field tests an asphaltic membrane remained impervious to passage of neutralized waste containing 10^{-3} curie/liter, and a prefabricated asphalt plank sagged

1.5 in., but did not rupture while supporting 2 ft of gravel. In survey studies, soil solidified with liquid silicate conditioners was stable in acid waste but not in water of caustic waste.

It was calculated that wastes from fuels irradiated to 10,000, 3,300, and 1,000 Mwd/ton and decayed 6 years would irradiate an asphalt lining to 10^9 r in 20, 79, and 300 years, respectively; with 10 years' decay the times would be 27, 95, and 365 years. Longer decay times offer little, if any, advantage. An open pit of 10^6 gal capacity could be constructed for $0.03 per gallon, and one with a concrete roof for $0.07 per gallon; corresponding casts for a 5×10^6 gal pit would be $0.02 and $0.05 per gallon.

ONRL-ESN-8-7/54

Reitz J R and Epremian E
EUROPEAN SCIENTIFIC NOTES,
Office of Naval Research, London, England, April 1, 1954, 14 pp. (5 refs).

This report describes in brief form some work being done in Europe in the fields of Physics, Chemistry, and Biosciences. The report deals specifically with the following subjects: (1) semiconducting compound, (2) slip plane of a dislocation jog, (3) the effect of ionizing radiation on high polymers, (4) kinetics and mechanism of inorganic reactions in solution, (5) a simple microcalorimeter, (6) the effect of dietary calcium level on bone absorption during pregnancy and lactation, (7) mutations in Saccharomyces cerevisiae, and (8) the correlation between histological and radiological appearances in injected bronchi.

ORO-53

Davidson W L
ELASTOMERIC MATERIALS AS SHIELDING COMPONENTS FOR NUCLEAR REACTORS,
The B. F. Goodrich Company, Contract No. AT-(40-1)-1309, July 1, 1951, 9 pp.

Inasmuch as this project has been active for only two weeks there is nothing definite to report yet in the way of progress. A compilation of important physical properties for existing elastomers has been started, and planning is underway on the items listed:

1. A study of the possibility of preparing synthetic elastomers with higher populations of H atoms per cc than occurs in presently existing elastomers.

2. An experimental compounding study covering the addition of large volume loadings (20 to 50%) of high atomic number elements into elastomers having a favorable H-content. Small loadings of boron will also be included in this program as well as the addition of materials such as ammonium dihydrogen phosphite. Efforts will be made to secure maximum physical properties in these vulcanizates, measured at room temperature and at 250°F. Means of stabilizing these compounds against aging at 250°F will likewise be investigated.

REIC-3 AD-149552

Broadway N J, et al.
THE EFFECTS OF NUCLEAR RADIATION ON ELASTOMERICS AND PLASTIC MATERIALS,
The Radiation Effects Information Center, Battelle Memorial Institute, Columbus, Ohio, Contract No. AF-33(616)-3171, May 31, 1958, 50 pp. (appendices and 37 refs).

This report presents the state of the art of the effects of nuclear radiation on elastomeric and plastic materials from 1947 to the present. A brief description of the mechanism of radiation damage is followed by detailed presentation of data summarizing the radiation effects information on numerous types of elastomers and plastics. Also, areas in which more research is needed are indicated. This report does not include information on the use of radiation for polymerization or vulcanization unless it has some bearing on effects of radiation on the finished polymer.

The information in this report is not new, but it is believed that it is sufficiently inclusive and is presented in a form which will make it valuable as a reference guide to the engineers designing nuclear weapons systems.

REIC-103158

Leininger R I
THE EFFECT OF NUCLEAR RADIATION ON FLUORINATED ELASTOMERS IN DIFFERENT ENVIRONMENTS,
Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, Contract No. AF-33(616)-5171, October 31, 1957, 2 pp.

This memorandum points out that fluorine-containing elastomers and plastics such as Viton-A and Teflon are widely used in seals and gaskets in lubricating and hydraulic systems because of their resistance to oils and thermal stability. Nuclear radiation causes rapid disintegration of such materials.

A table is included showing property changes of Viton-A and Teflon irradiated in air, argon, and jet turbine oil at $400^{\circ}F$ by a Co^{60} source.

REIC-TM-3

Broadway N J
THE EFFECT OF NUCLEAR RADIATION ON METALLO-ORGANIC COMPOUNDS AND ON POLYESTHYLENE,
REIC, Battelle Memorial Institute, Columbus, Ohio, Contract No. AF-33(616)-5171, February 15, 1958, 5 pp. (Bibliography - 11 refs).

This is a technical memorandum discussing the effects of reactor radiation on metallo-organic compounds and the relative effectiveness of neutrons, gammas, and electrons in producing damage to polyethylene.

REIC-TM-8

Broadway N J and Palinchak S
THE EFFECT OF NUCLEAR RADIATION ON SEALS, GASKETS AND SEALANTS,
The Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
Contract No. AF33(616)-5171, November 30, 1958, 9 pp. (16 refs).

Available information shows that most elastomers and a number of plastic materials have been utilized as seals. Of these, nitrile, neoprene, and Thiokol rubbers were irradiated as gaskets, seals, or sealants for operation below 300°F. Thiokol was evaluated in JP-4 fuel as a sealant and was found to perform satisfactorily to a dosage of 3.5×10^9 ergs g^{-1} (C). Nitrile and neoprene were evaluated only in air and were found to be resistant to 1×10^{10} and 1×10^9 ergs g^{-1} (C), respectively.

For operation above 300°F, fluorocarbon elastomers, Viton A and Elastomer 214 (copolymers of hexafluoropropylene and vinylidene fluoride) 1F4, also called PolyFBA (a polymer of 1, 1-dihydroperfluorobutyl acrylate), Kel-F elastomer (a copolymer of chlorotrifluoroethylene and vinylidene chloride), and a number of silicone materials were evaluated. In the nonelastomer class, Teflon was irradiated as a seal.

For the higher temperature range of operation, Viton A and Elastomer 214 tended to soften in air at 6×10^8 ergs g^{-1} (C), but in diester fluid at 400°F survived this amount in radiation resistance. Silicones, with the exception of Silastic 50-24-480, have been evaluated in air only. A dimethyl silastic O-ring retained flexibility in a vacuum seal at a dosage of 2×10^{11} ergs g^{-1} (C), while the Silastic 50-24-480, used as an oil seal for 48-50 hours at 450°F, has withstood a radiation dosage of 1.2×10^9 ergs g^{-1} (C).

REIC-TM-15

Schroeder M C
THE EFFECT OF NUCLEAR RADIATION ON HOSES AND COUPLINGS,
Radiation Effects Information Center, Battelle Memorial Institute, Columbus 1, Ohio,
March 31, 1959, 3 pp. (5 refs).

Standard aircraft hoses and couplings contain organic polymeric materials which are affected significantly by nuclear radiation. To determine the functional life of these items when exposed to radiation, some tests have been conducted at controlled conditions of temperature, pressure, type of internal fluid, and radiation-exposure rate. Buna N, a solvent-resistant synthetic rubber, and Teflon, a temperature-resistant plastic, were the hose materials for most of the tests.

These hoses were irradiated by gamma rays at conditions simulating actual operation for a specified time or until leakage occurred. Buna N hose withstood exposure dosages up to 4×10^8 ergs g^{-1} (C) before leaking, compared with 1×10^8 ergs g^{-1} (C) for Teflon hose, both at static pressures of 1200 psig and temperatures up to 350°F. The exposure dose required for failure of Teflon hose by intermittent pressure (0 to 1000 psig) was about 1×10^7 ergs g^{-1} (C) at 350°F.

REPF-108

EFFECT OF RADIATION ENERGY ON FLEXIBLE CONTAINERS,
Reprinted from the Activities Report, IX, 2(1957), The Research and Development Associates, Food and Container Institute, Inc., 11 pp. (50 refs).

This report discusses what happens to polymeric substances when exposed to gamma or beta radiation ions. The more common, polymeric, food packaging materials have been studied in varying degrees. Some of these discussed here are: polystyrene, polyethylene, mylar, pliofilm, halogenated plastics, cellulose, paraffin, and laminated materials.

RIA-53-4519

Eisler Stanley L
ENERGY RADIATION OF POLYMERS - A LITERATURE REVIEW,
Rock Island Arsenal, Rock Island, Ill., November 5, 1953, 15 pp. (31 refs).

This report is a compilation of information collected from a literature survey undertaken by Rock Island Arsenal. The general conclusions formed from the data found were that it is possible to produce crosslinking in various polymers and elastomers by means of high energy radiations. In addition, neutron irradiation of rubber vulcanates was found to be advantageous for natural rubber but degrading for polyisabutylene. Further, the irradiation of polyethylene was found to improve its resistance to heat and solvents which should be an indication that the heat and oil resistance of rubbers may be improved by radiation exposure.

RIA-55-3641 AD-121406

PHYSICAL PROPERTIES OF GAMMA RADIATION CURED ELASTOMERS,
Presented at OMRO Council on October 4-5, 1955, Rock Island Arsenal, Rock Island, Ill., (1953), 27 pp. (refs).

On the basis of a literature survey by Rock Island Arsenal in 1953, it was decided that an investigation of the effects of high intensity radiation on cured and uncured rubber and on the polymerization and copolymerization of monomers would be of interest and would augment the research program on rubber being carried out at the Arsenal. Cobalt-60 was used for the irradiation because of availability.

The rubber samples to be irradiated were sheeted from a rubber mixing mill to a thickness of approximately .070 in., placed between sheets of polyethylene, rolled into a cylinder, placed in canisters and into the irradiator. The samples were removed after various dosages and tests to determine stress-strain, oil resistance, and low temperature properties, and other physical property tests were conducted according to ASTM procedures. Rubber samples similar to those irradiated, but cured by conventional means, were prepared and tested for comparison.

SAE-57-4

Ference Michael, Jr.
EFFECTS OF RADIATION ON MATERIALS,
Society of Automotive Engineers, Inc., The Sheraton-Cadillac and Statler Hotels, Detroit, Mich., Annual Meeting, January 14-18, 1957, 13 pp. (14 refs).

It is the purpose of this paper to point out the nature of the changes that occur in the physical and mechanical properties of materials subjected to various types of radiation, and to discuss the results of some recent experiments on the effect of radiation on chemical systems.

In summary, radiation can produce significant changes in the properties of materials. However, there is a lack of fundamental data and theory to permit engineering calculation of the effect of radiation-induced point defects on the bulk properties of metals. Furthermore, there is no obvious economic advantage at present to irradiate metals in the bulk for possible beneficial effects. Most plastics degrade rapidly in intense radiation fields, although in the case of polyethylene, improvements in properties have been noted under moderate radiation doses. On the other hand, there is real promise in the use of radiation for initiating novel chemical reactions. For example, radiation-grafted copolymers offer the possibility of a new class of engineering materials with prescribed properties.

SCTM 283-59(16)

Montoya O
CORROSIVITY OF ROOM TEMPERATURE POLYSULFIED AND SILICONE SEALERS,
Sandia Corporation, Albuquerque, N. Mex., August 17, 1959, 11 pp.

Because of the tendency of some organic vapors to corrode electrical contacts and thereby increase contact resistance, a series of tests was performed at various temperatures to determine the difference in corrosivity with the different sealers. Typical sealing formulations which are commonly used at Sandia were chosen for these tests. This memorandum presents the results of these tests.

TID-8005

Ballantine David S
THE INITIATION OF CHEMICAL REACTIONS BY GAMMA AND OTHER IONIZING RADIATIONS,
Fission Products Utilization Project, Brookhaven National Laboratory, Upton, N. Y., February (1956), 6 pp. (19 refs).

There are three processes by which a gamma ray loses its energy to initiate a chemical reaction. They are the photoelectric process, the Compton process, and the annihilation process.

In radiation-induced polymerization there are believed to be six advantages for this type of catalysis, as follows:

1. Low Temperature Radical Initiation
2. Use of Low Pressures
3. Solid-State Polymerization

4. Different Temperature - Molecular Weight Relationships
5. Different Polymer Characteristics
6. Completely External Catalyst

UCRL-2704

Talbert Bert M and Lemmon Richard M
RADIATION DECOMPOSITION OF PURE ORGANIC COMPOUNDS,
University of California, Radiation Laboratory, Berkeley, Calif.,
Contract No. W-(7405)-Eng-48, August (1954), 36 pp. (60 refs).

A review is presented on the changes produced in organic compounds by radiation. In general the systems under consideration are restricted to water-free, air-free irradiations of single compounds. Data are reviewed regarding the types of compounds irradiated, the important G values, and the effects of functional groups on radiation sensitivity.

WADC-TR-52-197 (Part 3)

Bovey F A
SYNTHETIC RUBBERS FROM CARBON-FLUORINE COMPOUNDS,
Minnesota Mining and Manufacturing Co., for Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, Contract No. AF33(038)-515, September (1953), 193 pp.

This report describes the preparation and properties of fluorine-containing rubbers. The object of the work is the development of elastomeric materials which are resistant to the fuels, lubricants, and hydraulic fluids used in military aircraft and which are serviceable over the widest possible temperature range. Of the materials under development, the following appear to be of chief interest:

A. Perfluorobutadiene Copolymers. Copolymers of perfluorobutadiene with 1, 1-dihydroperfluoroalkyl vinyl ethers offer excellent high temperature resistance, low swelling in aircraft fluids, and high resistance to ozone.

B. Fluoroacrylates. In addition to the 1, 1-dihydroperfluoroalkyl acrylates, which have been described in earlier reports and which have outstanding solvent resistance but limited low temperature flexibility, newer classes of fluoroacrylates have been synthesized. Of particular interest are the γ-(perfluoroalkoxy)-1, 1-dihydroperfluoropropyl acrylates, which offer solvent resistance at least equal to that of the earlier series but are flexible at temperatures 25°C lower than the polymers of the 1, 1-dihydroperfluoro-alkyl acrylate.

WADC-TR-55-58 (Part I)

Loughborough D L, et al.
A STUDY OF THE EFFECTS OF NUCLEAR RADIATIONS ON ELASTOMERIC COMPOUNDS AND COMPOUNDING MATERIALS,
Research Center, The B. F. Goodrich Co., Brecksville, Ohio, Contract No. AF33(616)-2308, December (1954), 98 pp. (27 refs).

Comprehensive study of the effects of nuclear radiation upon elastomeric compounds and compounding ingredients was the main purpose of the development. The work was done at the B. F. Goodrich Company Research Center. Two-hundred-nineteen compounds were selected for study. One-hundred-ninety were selected and tested. Stress-strain and stress-relaxation measurements were made, along with special analyses of irradiation products. The investigations exhibit three principal results: (1) a catalog of stress-strain data for many elastomeric formulations has been compiled, (2) a group of inhibitors of radiation deterioration in rubber has been discovered, and (3) evidence has been gathered that the effect of cobalt-60 gamma irradiation on rubber is different in air than in high vacuum. The rubber compounds which are most resistant to deterioration are cited by recipe.

WADC-TR-55-58 (Part II)

Born John W
A STUDY OF THE EFFECTS OF NUCLEAR RADIATIONS ON ELASTOMERIC COMPOUNDS AND COMPOUNDING MATERIALS,
Research Center, The B. F. Goodrich Company, Brecksville, Ohio, Contract No. AF33(616)-2308, December (1955), 78 pp.

Continuous stress relaxation measurements in air detail the effects of temperatures ranging from 25° through 80°C on radiation damage to rubber compounds. The order of decreasing resistance to damage is natural rubber, GR-S, Neoprene GN, and Hycar 1002 for gum rubber compounds and GR-S, Hycar 1002, natural rubber, and Neoprene GN among the black compounds. Graphs illustrate these results.

Stress-relaxation measurements, volume swell measurements, infrared absorption analyses, and mass spectral analyses provided fundamental information about radiation damage. They showed further that heat and radiation damage differ significantly.

The Anti-Rad Screening Program and the study of the effect of radiation upon dynamic properties of rubber have reached the physical testing stage. Compounds containing 91 specially-selected potential anti-rads have received optimum cures, and samples have undergone gamma irradiation. The purpose of the screening is to provide criteria for the synthesis of specific new anti-rads.

WADC-TR-55-58 (Part III)

Born John W, Diller Dwain E and Rowe Eugene H
A STUDY OF THE EFFECTS OF NUCLEAR RADIATIONS ON ELASTOMERIC COMPOUNDS AND COMPOUNDING MATERIALS,
Research Center, The B. F. Goodrich Co., Brecksville, Ohio, Contract No. AF33(616)-2308, December (1956), 47 pp.

The effort to define, understand and prevent radiation damage to rubber continued during 1956. Research followed four main lines: the development of anti-rads to prevent radiation damage; infrared and mass spectral analyses to relate radiation stability to molecular structures of elastomers; stress-relaxation studies to define the mechanisms of radiation damage; and measurements of dynamic mechanical properties of representative rubber compounds after irradiation. Emphasis upon applied testing of end-item materials increased.

The best anti-rad extended the retention of tensile strength and ultimate elongation by natural rubber tread stock more than tenfold. The screening study is providing criteria for the selection of superior anti-rads. A new technique of mass spectral analysis promises to aid greatly in determining what molecular structural features impart radiation stability. Stress-relaxation measurements detail the important role of oxygen in radiation damage. Dynamic test data are given for eight representative rubber compounds.

WADC-TR-55-58 (Part IV) AD-206077

Born John W
A STUDY OF THE EFFECTS OF NUCLEAR RADIATIONS ON ELASTOMERIC COMPOUNDS AND COMPOUNDING MATERIALS,
The B. F. Goodrich Co., Research Center, Contract No. AF33(616)-2308, WADC, November (1958), 267 pp. (22 refs).

The research in this fourth year under the contract included the following: fundamental studies of the mechanism of radiation damage to high polymers and of the influence of molecular structure on the relative degree of radiation effects; basic attempts to protect textile filaments and cords from radiation damage; further screening of anti-rads for other conventional and newer elastomers; a search for and attempted synthesis of new and more effective anti-rads; applied studies of the separate and combined effects of heat and radiation on aircraft rubber compounds; irradiation and full-scale indoor testing of aircraft tires, with and without potential anti-rad protection; and formulation of a detailed program for the next end-item study, which will deal with "O" ring seals.

The work which is reported thus included fundamental, basic, applied, and end-item research. The results are stated briefly in the summary.

WADC-TR-56-296 AD-97254

Tomashot Robert C and Harvey Douglas G, 1/Lt. (USAF)
NUCLEAR RADIATION OF REINFORCED PLASTIC RADOME MATERIALS,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, September (1956), 48 pp. (3 refs).

Nine different reinforced plastic laminate materials, each made with a different laminating resin, and one alkyd-isocyanate foam core-glass fabric faced sandwich material were subjected to integrated gamma radiation dosages up to 10^9 roentgens. After completion of the radiation exposures, the materials were tested to determine the flexural, tensile, and compression strengths under both standard and wet conditions. The mechanical properties of the heat-resistant plastic laminates were also determined at elevated temperature.

Dielectric constant and loss tangent measurements were conducted on irradiated samples to determine the effect of radiation on the electrical properties of these materials.

Data obtained from these tests show that the mechanical properties were not significantly affected except for one epoxy-type resin laminate. None of the materials showed any significant change in electrical properties due to radiation.

WADC-TR-56-515 AD-142343

Terrell William B, 1/Lt. (USAF) and Humphries Jack T, 1/Lt. (USAF)
EFFECTS OF GAMMA RADIATION ON LINEAR POLYETHYLENE,
Wright Air Development Center, Wright Patterson Air Force Base, Ohio, February (1958), 39 pp. (Bibliography - 10 refs).

Linear polyethylenes have recently been developed which have empirical chemical formulae identical to those of common polyethylenes, but which differ in the molecular arrangement of the polymer chain. The physical properties of two linear polyethylenes were measured before and after gamma irradiation to afford a comparison with conventional polyethylene.

Measurements were made of the following properties as functions of total radiation dosage up to 10^9 roentgens: tensile strength, elongation, hardness, impact strength, specific gravity, water absorption, heat distortion temperature, dielectric constant, arc resistance, color, and infrared absorption. In addition, densities were determined as functions of both radiation dosage and temperature.

WADC-TR-56-534 (Part 3) AD-131029

Mixer R Y and Parkinson D B
NUCLEAR RADIATION EFFECTS ON STRUCTURAL PLASTICS AND ADHESIVES - PART III. EXPERIMENTAL RESEARCH,
Stanford Research Institute, Contract No. AF33(616)-3632, August (1957), 44 pp.

Nuclear radiation damage mechanisms are presented for model compounds representing several typical aircraft structual adhesives and laminates. Laminates were prepared from eight resin-curing agent systems and irradiated to 10^9 and 10^{10} rep for determination of the threshold dose for damage. The threshold dose for one system was found to be less than 10^8 rep. In the case of typical amine-cured, epoxy-type adhesives, radiation appears to cleave the amine groups with volatilization of some fragments and to crosslink the polymer chain. Small amounts of chemical changes result in large changes in physical properties of the cured adhesive. Beta and gamma irradiation have produced equal effects on one vinyl-phenolic and one epoxy-type adhesive. One organic scintillator, 2, 5-diphenyloxazole, appears to be partially effective in preventing irradiation damage in an epoxy-type adhesive.

WADC-TR-56-557 (Part I) AD-118111

Schmidt Donald L and Johnson Robert H, 1/Lts. (USAF)
EFFECTS OF GAMMA RADIATION ON AIRCRAFT TRANSPARENT MATERIALS,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, March (1957), 24 pp. (13 refs).

The effects of gamma radiation on various optical, mechanical and thermal properties of transparent plastic materials were investigated. Gafite, Plexiglas 55 and Sierracin 611 materials were irradiated in a gamma facility to total absorbed doses of 10^6 to 10^{10} ergs per gram and then evaluated in accordance with standard testing procedures.

The physical properties of the transparent plastics were not significantly affected by a radiation exposure of 10^7 ergs per gram, or less. At higher absorbed doses, most of

the physical properties were degraded. In addition, several desirable changes in specific physical properties were also obtained.

The optical properties of the transparent plastic materials were more susceptible to radiation-induced changes than were the mechanical or thermal properties.

WADC-TR-57-92 AD 130920

Marcus Hyman and Zaleski Frank V
EXPANSION CHARACTERISTICS OF MARLEX 20 AND MARLEX 50,
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, July (1957), 21 pp. (3 refs).

A suitable technique was developed for volume dilatometry of plastic materials and the thermal behavior of two commercial linear polyethylene plastics. Marlex 20 and Marlex 50 were observed.

The technique consisted of sealing a test sample in a glass tube with mercury as the confining fluid. The change in volume of mercury as evidenced by its rise in a capillary tube was noted at different temperatures. The volume expansion of the test samples was calculated from the known expansivities of glass and mercury.

The dilatometers used were immersed in an electrically heated oil bath equipped with a motor-driven stirrer to insure a uniform temperature distribution.

WA-OMRO-13A-B3

Matlack J D
HIGH ENERGY RADIATION IN THE FIELD OF PLASTICS,
Picatinny Arsenal. Presented at Conference on Effects of Nuclear Radiations on Materials, October 1-2, 1957, Watertown Arsenal, Watertown 72, Mass., 10 pp. (1 ref).

Data are presented which show the effect of nuclear radiation on plastic materials from two points of view, i.e., changes: (a) in molecular structure, and (b) in mechanical properties. This presentation is in the nature of a review and deals with information available from all sources including work being done by Picatinny Arsenal.

WAPD-48

Mayburg S and Lawrence W L
THE CONDUCTIVITY CHANGE IN POLYETHYLENE DURING GAMMA IRRADIATION,
Atomic Power Division, Westinghouse Electric Corp., Contract No. AT-(11-1)-Gen-14, January 2, 1952.

The effect of Co^{60} irradiation on the direct current conductivity of polyethylene has been determined up to an intensity of 4000 roentgens per hour at room temperature. Temperature data serve to suggest an ionic mechanism.

WOBC-72324

Shaver Richard C and Semegen Stephen T
THE EFFECTS OF NUCLEAR RADIATION ON ELASTOMERIC COMPOUNDS AND COMPOUNDING MATERIALS FOR USE IN NAVAL MATERIALS,

Research Center, The B. F. Goodrich Company, Brecksville, Ohio, May (1958).

Elastomer recipes were chosen to give a cross section of end-use gaskets, shock-mounting and hose stocks, and a variety of polymers. Also included in the program was the evaluation of these same compounds containing anti-irradiation chemicals.

Sixteen compounds were selected from the rubber formulary. They included neoprene compounds, Hycar compounds, SBR compounds, and natural rubber compounds. Data show the limits to which polymeric compounds can be exposed to nuclear radiation (Co^{60}) and remain serviceable.

Y-904

Sachs Frances
THE EFFECT OF ALPHA-, BETA-, GAMMA- AND X-RAYS ON ORGANIC COMPOUNDS, A literature search. Carbide and Carbon Chemicals Co., a Division of Union Carbide and Carbon Corp., Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, August 18, 1952, 92 pp.

This report is a literature search on the effect of alpha, beta, gamma, and X-rays on organic compounds. There are 35 articles listed for effects of alpha particles, 25 articles on effects of beta particles, 42 articles on effects of gamma particles, and 107 articles on effects of X-rays. There are 27 articles on general items of interest and related material.

PROPELLANTS, EXPLOSIVES, AND ASSOCIATED TOPICS

ORNL-1720

Rosenwasser H
EFFECTS OF GAMMA RADIATION ON EXPLOSIVES -- FINAL AND SUMMARY REPORT ON ARMY ORDNANCE PROJECT TA3-5003R-STABILITY AND REACTIONS OF EXPLOSIVES,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, December 6, 1955, 28 pp. (18 refs).

This is the final report on the joint investigation of the effects of gamma radiation on explosives by the Oak Ridge National Laboratory and the Picatinny Arsenal. The data obtained by subjecting different explosives at various temperatures to the influence of an intense gamma-radiation field are presented. The work showed that the different explosives exhibited varied resistances to the treatment and gave an indication of the direction future work should follow. Explanation is required for the sensitization of the primers and detonators used, as well as the peculiar characteristic of gas formation by some of the explosives following irradiation. More generally, however, a need for a study of the radiation chemistry of explosives is indicated. It is hoped that provision will be made for such a study.

REPF-109

Rhodes R T
ABILITY OF THE XMC-1107 TO FUNCTION AFTER EXPOSURE TO A BLAST SPECTRUM OF RADIATION,
Sandia Corporation (Interoffice Memo), Albuquerque, N. Mex., July 17, 1959, 4 pp.

The XMC-1107 must function after exposure to a blast spectrum of radiation. This memo outlines a plan to demonstrate the component's ability to meet these requirements. In addition test data are also included. Conclusions are stated.

S-13447

Bollo F G, et al.
ROCKET FUELS DERIVABLE FROM PETROLEUM,
Quarterly Detailed Report, November, December 1952 and January 1953, Shell Development Co., Emeryville, Calif., Contract No. NOas 52-808-c, (1953), 38 pp. (15 refs).

Work during this second quarter included synthesis and preliminary screening of several new compounds as liquid rocket fuels. Included in this group were low freezing point conjugated diacetylenes, a triethyl phosphorous triamide, two organoboron compounds, and the product of reaction of acetylene with hydrazine. An investigation of procedures for synthesis of large lots of selected fuels was also undertaken.

Work was continued on more detailed evaluation of blending agents to upgrade the ignition quality and improve the combustion characteristics of aircraft JP-4 fuel; on the development of hypergolic acetylenic-phosphorous triamide fuels equal or superior to JP-4 in specific impulse; and on organoboron compounds. Arrangements are being made to obtain small scale rocket motor tests on representative materials from each of these groups in order to gain some idea as to their combustion characteristics.

So far the most effective blending agents for JP-4, based solely on ignition data, are the phosphorous triamides; but information on their effect on combustion is urgently needed. In view of the importance of this application, it is receiving particular attention in our program and all new fuels showing good ignition qualities are tested as blending agents in JP-4 fuel for their effect on ignition quality. The acetylenic-phosphorous triamide blends have excellent ignition characteristics, and if their combustion quality is favorable, they might be considered as a replacement for JP-4 blends, should attempts to improve combustion characteristics of the latter be unsuccessful. The organoborons are attractive because of the estimated high specific impulse. The results of storage stability, gasket compatibility, and corrosivity tests with RF-208 are reported.

Development of evaluation methods, particularly for storage stability, is discussed.

S-13477

Conklin G W, et al.
ROCKET FUELS DERIVABLE FROM PETROLEUM,
Quarterly Detailed Report, February thru April 1953, Shell Development Co., Emeryville, California, Contract No. NOas 52-808-c, (1953), 36 pp.

During the third quarter of the current contract, synthesis work and preliminary screening have continued with three classes of potential rocket fuels. With unconjugated diacetylenes, emphasis has been placed on the longer chain compounds which promise improved stability with only small reduction in impulse. Several new organophosphorus compounds containing amine groups have been prepared and examined as ignition upgraders. In the organonitrogen field acetylene-hydrazine reaction products are explored.

In the blending program advantages have been indicated for fuels consisting of a blend of acetylene-hydrazine reaction products. The improvement of the burning characteristics of JP-4 has also been further studied.

SCTM 53-59(51)

Smith R E
UNDERGROUND MINING WITH NUCLEAR EXPLOSIVES,
Sandia Corporation, Albuquerque, N. Mex., May 14, 1959, 31 pp. (2 refs).

Mining methods have developed in the course of centuries from the breaking of ore by hand from small but rich deposits to modern techniques by which 20,000 to 50,000 tons of low-grade ore can be removed each day from deposits hundreds of feet underground. A further advance in technique is proposed and discussed; namely, the use of nuclear

explosives in underground mining. Such a method would add to our national resources by making it possible to mine deposits which cannot now be economically exploited. Proposed nuclear modifications are presented, together with the potentialities and limitations of the proposed technique.

SCTM-80-57 (51)

Vortman L J
FALLOUT FROM A HYPOTHETICAL 1-MT SURFACE BURST AT ALBUQUERQUE,
Sandia Corporation, Albuquerque, N. Mex., Contract No. AT(29-1)-789, March 10, 1957, 7 pp.

The direction and extent of fallout from a hypothetical 1-mt surface burst at Albuquerque are examined using available 1956 wind data.

WT-70 X-21110

Broido A, et al.
THE EFFECT OF THERMAL RADIATION ON MATERIALS,
U. S. Naval Radiological Defense Laboratory, San Francisco, Calif., September (1951), 245 pp.

Project 6.2 was set up partly to obtain information concerning the characteristics of thermal radiation from an atomic bomb detonation, necessary to the prosecution of the general laboratory thermal program and partly to make exposures of materials which could not be done in the laboratory. The thermal-radiation characteristics of greatest interest were the total energy, the time-intensity relation, and the spectral distribution. Measurements of these characteristics were made at several distances using calorimeters with oscillographic recorders, rotating drums with sensitive-paper indicators, and passive receivers consisting of metal foils. A number of the materials used in the field were previously exposed to laboratory sources. Those materials used in the incendiary program were chosen for studies of the effects of such factors as area, backing material, geometry, and reflectance on the incendiary characteristics. Documentation was carried out by means of motion-picture photography.

The total thermal-energy values at approximately 2 miles from ground zero were found to be about one-half of those expected. The values at the closer stations were found to be even smaller fractions of expected values. Time-intensity curves indicate that this further reduction is due to obscuring material arising at about 0.5 sec between ground zero and the points at which measurements were made. Peak intensities were reached in approximately 0.25 sec, and it is probable that the most thermal damage occured within 1 sec. Since the shape of the thermal pulse was different for each station, it was necessary to make time corrections in the analysis of the passive-receiver data.

Rough spectral measurements indicated that the bulk of the thermal radiation was in the visible portion of the spectrum, although all measurements were uncertain to 10% of the total thermal energy. With this uncertainty no ultraviolet energy was found, and the infrared energy beyond 1μ was measured to be only 10%. On the basis of these results, all existing laboratory sources would appear to overemphasize the infrared portion of the spectrum.

A considerable amount of data was obtained concerning the effect of the field radiation on materials previously exposed to laboratory sources. A comparison of field and laboratory effects under similar conditions of exposure will provide an indication of the extent to which the laboratory sources simulate the field source.

The results of the incendiary experiments showed that small individual samples of solid combustible materials such as wood and cloth did not sustain fires for more than 1 sec or so. For the stations used, no fires existed at the time of arrival of the blast wave. However, indications are that the proper combination of materials arranged in suitable geometry may result in sustaining primary fires.

The nature of the results obtained, particularly the effect of obscuring material, indicates the need for additional information from future atomic-bomb-detonation field tests. In particular, it is considered highly desirable to obtain information from several sizes of detonations and for air bursts.

SHIELDING

AECD-3134 ORNL-667

Tirpak Edward G
REPORT ON THE USE OF BARYTES AGGREGATES IN CONCRETE FOR SHIELDING PURPOSES,
Engineering Dept., Laboratory Design Sect., Oak Ridge National Laboratory, Oak Ridge, Tenn. Contract No. W-7405-Eng-26, April 13, 1950, 20 pp.

The report discusses the general nature and need for shielding material to protect man from overexposure. Several materials can be used as shields, but in this report steel and lead are used for comparison with barytes aggregates. One disadvantage of concrete for heavy shielding is the great thickness required. On the other hand, structural strength, workability and adaptability, and low cost per unit of shielding are in its favor.

Several concrete mixes were tried so as to arrive at one suitable to the shielding requirements. The report discusses and summarizes the methods of testing and pouring of the different mixes. The concrete was tested for effects of heating.

AECD-3625

McKinney V L and Rockwell Theodore, III
BORAL: A NEW THERMAL NEUTRON SHIELD - SUPPLEMENT I,
Technical Division and Reactor Experimental Engineering Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, May (1954), 39 pp.

A technique has been developed for making large sheets or castings of B_4C and aluminum complex for absorption of thermal neutrons without production of hard gamma radiation. The 1/4" sheet has the following properties:

Boron Content: 50% B_4C (or 40% B) by volume, 0.91 g B/cm^3 or 0.58 g B/cm^2 of 1/4" sheet.

Thermal Neutron Attenuation of 10^{10} in 1/4" (based on $\sum_{th}^{B} = 100$ cm^{-1}).

Density: 2.53 g/cm^3 or 3-1/4 lb/ft^2

Cost: 15-20 \$/ft^2

Tensile Strength: 5500 psi (10 times concrete, 1/10 mild steel, about equal for best plastics).

Thermal Conductivity: Somewhat better than steel (more precise measurements in progress).

Can be sheared, sawed, welded, punched, drilled, tapped, rolled, and hot-pressed. Sheets 7' by 33' by 1/4" are in preparation for shearing to 5' x 6' test sheets.

It is felt that this material will have many uses where a large thermal neutron flux must be absorbed without production of hard gammas, e. g., inner section of reactor shields, shutters for thermal columns, instrumentation.

AECD-3653

Barfield W D
A COMPARISON OF DIFFUSION THEORY AND TRANSPORT THEORY RESULTS FOR THE PENETRATION OF RADIATION INTO PLANE SEMI-INFINITE SLABS,
Los Alamos Scientific Laboratory, University of California, Los Alamos, N. Mex., Contract No. W-7405-Eng-36, June (1954), 39 pp.

The penetration of radiation into plane semi-infinite slabs of material has been calculated numerically by means of the time-dependent transport theory (Boltzmann equation) and the approximate "diffusion theory." Quantitative results are given for the case of a nonscattering material with constant absorption cross section, and for the general case of a scattering material (boron) with absorption coefficient a function of energy. Results show that the diffusion theory calculation gives an energy penetration which is too large, but that in a time during which the diffusion wave penetrates to a depth corresponding to a few mean free paths, the rate of energy penetration calculated using the diffusion approximation approaches the value calculated using the exact theory.

AECD-3769

Poleczny M P
COFFIN AND COFFIN HANDLING,
Materials Testing Reactor Project, Design Report No. 21, Argonne National Laboratory, December 5, 1949, 15 pp.

Special shielded containers, called coffins, will be used for removing radioactive beam hole plugs from the reactor, transporting them to plug storage and inserting them therein. Alternately, a coffin may be moved up to a "hot" laboratory or "cave" where, by remotely operated manipulating devices, operations such as charging of experimental samples may be safely conducted, after which the plug may be reinserted into the reactor.

In this report no attention has been given to the more or less standardized type of coffin used for the transportation of isotopes and irradiated samples nor to special designs for the transport of radioactive graphite pebbles or any other special purposes which may never arise. Attention has been given only to the handling of dummy and experimental beam hold plugs.

This report gives a detailed disclosure of the problem, design data, and several appendices.

AECD-3886

Warren Curtis
THE ENGINEERING PROPERTIES OF IRON-LIMONITE CONCRETE FOR CONSTRUCTION OF BIOLOGICAL SHIELDS,
Hanford Works, Richland, Wash., January 30, 1952, 8 pp.

This is a letter intended to provide a brief summary of the information presently available on the engineering properties of iron-limonite concrete with the view of adapting such concrete for use as biological shielding material in a Hanford pile. By reducing materials and fabrication costs, such an adaption might effect a savings of at least two million dollars per pile over the present iron-masonite laminated shield structure.

After carefully reviewing the results of tests made to determine the mechanical and thermal properties of iron-limonite concrete, it can be concluded that such concrete has engineering properties which would make it acceptable for use as a biological shielding material provided its properties are not adversely affected by irradiation.

AECD-3978

Chapman G T and Storrs C L
EFFECTIVE NEUTRON REMOVAL CROSS SECTIONS FOR SHIELDING,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, September 19, 1955, 148 pp.

The effective removal cross-section concept as applied in shield calculations is discussed and a method of determining the numerical value of this cross section from LTSF experimental data is presented. Radiation intensity measurements in water beyond some 20 elements and compounds and the corresponding removal cross-section values are reported. These values are useful in determining the relative shielding effectiveness of the various materials, but can be used with complete assurance for shielding calculations only when the geometry under consideration closely resembles that employed at the LTSF. Specifically there must be many relaxation lengths of hydrogeneous shield following the material.

A graphical comparison of the effective removal cross sections and the total cross sections at a high neutron energy (8 Mev) is also made and should be applicable to shield calculations. In addition, calculations are presented of correction factors for various values of the water thickness, sample thickness, and attenuation lengths in order to facilitate the calculation of the removal cross section from future measurements.

This report also discusses the description of the Lid Tank Shielding Facility (LTSF), procedure of removal cross-section measurements of LTSF, and procedure for removal cross-section calculations from the data. Numerous tables and curves are included.

AECD-4233 KT-85

Bowman W H, James D L and Roarty J D
THE DECAY OF INDUCED ACTIVITY IN PORTLAND, BARYTES, AND BROOKHAVEN CEMENTS,
Massachusetts Institute of Technology, Engineering Practice School, Oak Ridge, Tenn., August 23, 1950, 27 pp. (Bibliography - 6 refs).

The materials used in pile construction must be of such a nature that little response is shown to neutron bombardment and that the induced activity decay rapidly. Maintenance is facilitated since personnel may enter the irradiated regions shortly after pile shutdown.

Three types of cements, Barytes, Brookhaven, and Portland, were exposed in the ORNL Reactor for periods of seven and twenty-eight days, and the induced activity was measured in a 100% -geometry ionization chamber responding only to gamma radiation. The activity was plotted as a function of the length of decay and the half lives of the active materials determined therefrom. Using these data the probable identity of the elements giving rise to this activity was determined from a search of the isotope tables.

The absorption of radiation by lead from these samples was measured with a Geiger-Mueller counter.

It will be observed that the Portland cement has the least activity and that the activities of the Barytes and Brookhaven cements are about 10 times greater. Other properties being equal, the Portland is the most promising for use in irradiated regions. It has an additional advantage in that there are no extremely active short-lived materials in it although this is of no consequence if a cooling-off period of two or three days is available.

In order to make these results easy to compare with results obtained from samples irradiated with a different neutron flux, the activities are presented for a standard radiation of 10^{12} neutrons/(sq cm)(sec).

AECU-1211

Ruddy John M
GAMMA-RAY SHIELDING FOR ENGINEERING REFERENCE,
Brookhaven National Laboratory, February 15, 1951, 23 pp. (Bibliography - 30 refs).

Data are provided here for computing gamma-ray attenuation through medium and heavy shields of lead, iron, or concrete; for light shields or nuclides with very weak gamma rays, a check for beta-ray protection is advisable. For higher energy gammas, over 10 Mev, and for sources emitting an appreciable quantity of neutrons, both exceptional cases, a separate determination of shielding attenuation for mesons and fast and/or thermal neutrons and their secondary effects should be made. Other than this, the gamma-ray shielding described will, in general, adequately shield from other rays or particles.

Although the literature covering the theoretical and experimental behavior of gamma rays penetrating shielding material is not complete in the higher energy ranges above 5 Mev, or for heavier layers of absorbers, sufficient data were obtained to prepare simplified equations, tables, and figures for engineering practice after the present basis for gamma-shielding computations was brought into agreement with the latest observations and theoretical data.

AECU-3510

Dennis R, Purohit S N and Brownell L E
PROCEDURES FOR SHIELDING CALCULATIONS-TECHNICAL REPORT NO. 1,
Engineering Research Institute, University of Michigan, Ann Arbor, Mich.,
Contract No. AT(11-1)-162, January (1957), 106 pp. (104 refs).

This report deals with the shielding of nuclear radiation facilities. It is divided into two sections. The first part of the report deals with the gamma-radiation shielding.

The concept of the "build-up factor" is discussed in detail. As an illustration, the analysis of the heterogeneous gamma-radiation spectrum from the MTR fuel element from the point of view of shielding has been given. The analytical expression for the build-up factor, as obtained by Taylor, has been used in the above analysis. The second part of the report discusses the problems involved in shielding a nuclear reactor. A sample calculation of the shielding of a nuclear reactor is given. The report contains graphs for determining the standard integrals involved in calculating the radiation flux for standard geometries and also an extensive bibliography.

AECU-3862

Tarbox Leon A and Beck Christian
ENGINEERING STUDY ON REACTOR SHIELDING,
Engineering Branch, Division and Construction and Supply, U. S. Atomic Energy Commission, Washington, D. C., April (1958), 17 pp. (7 refs).

A study was made to determine variation in construction costs for biological shielding vs. changes in radiation levels and exposure to personnel working around a reactor. The study is based on a hypothetical production-type reactor; however, various assumptions have been made to simplify and clarify the analysis. These assumed conditions may be more applicable to those related to an industrial power reactor. Comparisons are made based on the cost of constructing a biological shield that will reduce the radiation level to 1 mrem/hr at the outside face of the shield, a conservative criterion which is often used. Estimates of comparative costs are made for radiation levels higher by factors of 10, 50, and 100. Comparative cost estimates have also been made for biological shields made of less costly construction materials than in the assumed basic shield. The analyses include all cost items involved, such as reductions in the primary biological shield, in the building size, in the secondary shielding walls, and in tubings, etc. In a reactor, such as the assumed hypothetical reactor, the reduction in cost, if the radiation levels were allowed to be increased by a factor 10, was estimated to be $237,000, or 10.3% of the $2,308,000 total costs of the primary biological shield. The possibility of cost reductions has been analyzed in relation to the computed radiation levels in the areas around the reactor, and the expected exposure to the individuals working in these areas.

AERE-R/R -872

Price B T
THE ATTENUATION OF GAMMA RADIATION AND NEUTRONS IN THE SHIELD BEPO,
Atomic Energy Research Establishment, Harwell, Berkshire, England, February 28, 1952, 13 pp. (6 refs).

Measurements have been made of the attenuation of radiation by the barytes concrete discharge face shield of the Harwell pile. The integrated dose of gamma radiation is found to fall off exponentially with a 10-folding length of 8.2 ± 0.2 inches. Fast neutrons (E > 1 Mev) are attenuated with a 10-folding length of 7.3 ± 0.3 inches. Thermal neutrons show a gradual increase in 10-folding length as distance into the shield increases. At a depth of iron and concrete equal to 36" the 10-folding length is 8.1 ± 0.4 inches.

Some measurements on the attenuation of neutrons in the thermal shield of the pile are also included.

Minimum thicknesses of shielding required for health and instrumental tolerances are discussed.

AERE-R/R-1271

Horton C C
SHIELDING STUDIES - II. THE DISTRIBUTION OF GAMMA-RADIATION IN GRAPHITE MODERATED URANIUM REACTORS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, October 14, 1953, 23 pp. (16 refs).

The distribution of gamma radiation in the core, reflector, thermal column, and a mock thermal shield of BEPO has been studied using a "homogeneous" ion chamber. The chamber is of simple construction and its output current is a known function of the gamma energy deposited in the chamber volume.

The results may be fitted by formulae based on a simple method of calculation of gamma-ray transmission through matter. It is shown that the radiation escaping from a typical graphite-uranium reactor consists mainly of gamma rays from neutron capture in the moderator and thermal shield, these have an effective energy of about 5 Mev. The gamma radiation in the core of such a reactor is shown to consist mainly of soft gamma rays originating in the fission process and from decay of the fission products.

Using these results the distribution of gamma rays in the shield of BEPO has been calculated, and shown to fit data obtained by other experiments over the range of measurement.

AERE-R/R-1943

Salmon A
THE DIFFUSION LENGTH OF THERMAL NEUTRONS IN PORTLAND CONCRETE,
Atomic Energy Research Establishment, Harwell, Berkshire, England, March (1955), 12 pp. (3 refs).

The diffusion length of thermal neutrons in Portland Concrete has been measured to provide fundamental data for shielding studies. The composition and environment of the concrete was measured and is noted. The determined value of the diffusion length was (7.30 ± 0.2) cm. The density of the concrete was (2.23 ± 0.02) gm. cm^{-3}. The diffusion length was thus (7.04 ± 0.21) cm. at a density of 2.3 gm. cm^{-3}.

AERE-R/R-1963

Halliday D B
HEAT RELEASE IN CONCRETE REACTOR SHIELDS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, November 17, 1954, 16 pp.

The purpose of this paper is to analyse the way in which heat is deposited in a concrete reactor shield, to discuss its probable limitations and how these might be modified by design and experiment.

It is of great economic interest to determine to what extent concrete can be used as the innermost part of the shield, thus saving more expensive structural and shielding materials. The use of concrete depends on the quantity and distribution of the heat released in the shield by the radiation; methods of removal of heat from the shield, also the thermal conductivity of the concrete, both of which control the maximum temperature and maximum gradient in the shield; and the maximum irradiation damage flux for the concrete, for a given lifetime before deterioration takes place.

The heating in a reactor shield is due to a mixture of fast neutrons, thermal neutron and gamma irradiation, and once it has been split up into these separate groups, the heat released and temperature attained can be readily calculated by the method as outlined in this report.

Experiments carried out in B. E. P. O. suggest that a concrete shield would have an irradiation life of at least 10 years in a flux of 10^{11} n/cm^2-sec.

AERE-RP/R-1942

Dyson J A (Miss) and Harrison J R
THE DEPENDENCE OF FAST NEUTRON ATTENUATION IN PORTLAND CONCRETE ON ITS HYDROGEN CONTENT,
Atomic Energy Research Establishment, Harwell, Berkshire, England, April 11, 1956,
7 pp. (2 refs).

The effect of varying the hydrogen content in a typical Portland concrete on the attenuation of fast (> 1 Mev) neutrons has been investigated using the theory developed by Spinney. It is shown that increasing the hydrogen content from 0.1 to 1 percent (by weight) changes the asymptotic relaxation length from 10.6 to 8.9 cms.

AERE-RS/L-3

Horton C C
THE THEORY AND PRACTICE OF SHIELDING,
Atomic Energy Research Establishment, Harwell, Berkshire, England, November 25, 1954,
16 pp. (2 refs).

In the operation of a nuclear reactor, a small fraction of the neutrons generated in fission will escape entirely from the system; and nearly all of the neutrons captured within it produce γ-rays by excitation of the nuclei in which they are captured. The design of the reactor must,then, incorporate a means of reducing the fluxes of escaping neutrons and γ-rays to a tolerable level, and since this shield is nonproductive, it must be kept to the cheapest or smallest size possible consistent with this object. The level of radiation attained outside the shield is not necessarily restricted only in this way; however, in many cases it may be necessary to consider the effect of the radiation leaking through the shield on the instruments which will be used in conjunction with the reactor. In addition to this basic aim, the field of shielding design covers many other considerations, these include:

(a) Calculation of the heat released in the shield by absorption of the reactor radiation.

(b) Shielding required for components which have been irradiated in the reactor.

(c) Effects of coolant irradiation and streaming of radiation down coolant ducts.

(d) Evaluation of the biological effects of radiation.

AERE-T/R-727

Mandl M E (Mrs.)
ENERGY FLUX AND AVERAGE ENERGY OF NEUTRONS SCATTERED BY THE WALLS OF A LABORATORY,
Atomic Energy Research Establishment, Harwell, Berkshire, England (1951), 14 pp. (3 refs).

The energy flux of neutrons scattered back to the source is calculated for a source at the centre of a spherical room.

The average energy of the returned neutrons is calculated by comparison with the formula given in T/R 563 for the neutron flux.

The walls of the room were assumed to be of some noncapturing material having scattering properties similar to concrete.

ANL-4879

Doe William B
ZINC BROMIDE SOLUTION FOR USE IN SHIELDING WINDOWS,
Remote Control Engineering Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-(31-109)-Eng-38, September (1952), 30 pp.

Large-area dense-material shielding windows are useful for viewing into enclosures containing high levels of radiation. They are particularly desirable when used in conjunction with rapid manipulators, such as the master slave type developed at Argonne.

In the introduction this report discusses several types of shielding possibilities. Some of these are lead acetate in water, acetylene tetrabromide, and concrete.

This report is specifically directed toward a discussion of zinc bromide solution for use in shielding windows. Zinc bromide is discussed with respect to chemical stability, radiation stability, low temperature stability, optical transmission, corrosion of container materials, filtration and handling of the solution, and measurement of haze.

ANL-4903

A MANUAL FOR REMOTE VIEWING,
Remote Control Engineering Division, Argonne National Laboratory, P.O. Box 5207, Chicago 80, Ill., Contract W-(31-109)-Eng-38, August 11, 1952, 44 pp. (Bibliography - 4 refs).

The observation of a procedure involving radioactive material is complicated by the necessity of seeing through or around the required biological shield. "Seeing" in general denotes receiving the same visual impressions as those of an observer moving around inside the shield. This report discusses the requirements, basic techniques, and submerged operation of such a viewing system. Also discussed are specific types of viewing windows, simple reflecting systems, periscopes, and closed circuit television.

APEX-176

Moteff John
MISCELLANEOUS DATA FOR SHIELDING CALCULATIONS,
Atomic Products Division, Aircraft Nuclear Propulsion Dept., General Electric Company, Evendale, Ohio, December 1, 1954, 117 pp.

This report represents an effort to consolidate under one cover the data of importance to the shielding groups. The major topics considered are as follows:

Gamma Ray Attenuation Coefficients
Buildup Factors
Fission Product Gamma Spectrum
Geometric Considerations
Flux to Dose Conversion
Attenuation Fission Product Gamma Rays Through Lead, Iron, and Water

BNL-433(C-24)-16

Richtmyer R D
RESONANCE CAPTURE CALCULATIONS FOR LATTICES BY THE MONTE CARLO METHOD,
AEC Computer Facility, New York University, New York, N. Y. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 8 pp.

The processes occurring when neutrons are slowed down in a hexagonal lattice of fuel rods (usually U) in a moderator (usually H_2O) are simulated on the Univac by Monte Carlo techniques and various quantities, including the resonance capture probability, $1-\rho$, are estimated by more or less usual sampling methods. Effects taken into account include: energy loss in collisions with heavy atoms as well as light ones, resonance scattering as well as resonance absorption, Doppler broadening, absorption in the wings of the resonances, and cladding of the fuel rods. A statistical accuracy of about 2% in $1-\rho$ can be obtained. Differential effects (e.g., due to a temperature change) can be obtained with greater accuracy by use of a special technique. From the known properties of the lowest 18 resonances of U^{235} and an estimated statistical description of the higher resonances, values are obtained which agree roughly with the semiempirical formula for ρ.

BNL-433(C-24)-17

St. John D S
RESONANCE ABSORPTION IN HEAVY WATER REACTORS,
Savannah River Laboratory, Aiken, South Carolina. Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 2 pp.

The resonance absorption of various fuel shapes in heavy water reactors is being studied at the Savannah River Laboratory. The proposed experimental program will determine the ratio of resonance to thermal absorptions in U^{238} in various geometries. These data will be used to deduce effective resonance cross sections. A Monte Carlo code is being prepared for the IBM 650 to compute resonance absorption in a variety of elements. Neutrons are followed through the energy region of resolved resonances, at a rate of 50 to 100 per hour.

BNL-433(C-24)-18

Sampson J B
ATTEMPTED MONTE CARLO CALCULATIONS OF RESONANCE ESCAPE PROBABILITY IN A GRAPHITE LATTICE,
Knolls Atomic Power Laboratory, Schenectady, New York, Paper given at Brookhaven Conference on Resonance Absorption of Neutrons in Nuclear Reactors, September 24-25, 1956, 3 pp. (7 refs).

Monte Carlo calculations have been carried out of resonance capture phenomena in the 6.7- and 104-ev resonances of U^{238} in a graphite moderated lattice. Values obtained for $1-\rho$ were 0.0258 ± 0.0017 and 0.0012 ± 0.0013, respectively, for these resonances. The influence of the large scattering component in the 104-ev resonance was indicated to be small. For the 6.7-ev resonance, several associated phenomena were also determined including spatial distribution of flux at several energies. The statistical accuracy of the results and the calculation time required were somewhat disappointing in this particular coding.

CF-48-9-183

Smith Nicholas M, Jr.
THE ABSORPTION AND SCATTERING OF RADIATION BY RANDOM AGGREGATES OF PEBBLES,
Oak Ridge National Laboratory, Oak Ridge, Tenn., September 23, 1948, 27 pp.

This report discusses absorption and scattering of radiation by random aggregates of pebbles. The general theory, comparison with experiment, channelling effect factor, channelling effect in diffusion and channelling effect when interstices are filled are discussed.

CF-50-8-17

Blizard E P
SHIELDING OF NUCLEAR REACTORS. LECTURE II - NEUTRON AND GAMMA CROSS SECTIONS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., August 8, 1950, 14 pp.

All interactions of neutrons with nuclei can be divided into two classes: those in which a compound nucleus is formed, and those in which the neutron is diffracted around a nucleus. Topics discussed are shadow scattering, cross-section limits at high energy, asymmetry of scattering, nuclear resonance, and cross sections from the shielding viewpoint.

The three distinct processes by which gamma rays can interact with matter - photoelectric effect, compton effect and pair production - are discussed.

CF-50-8-49

Blizard E P
SHIELDING OF NUCLEAR REACTORS. LECTURE III - GEOMETRY TRANSFORMATIONS FOR SHIELDING,
Oak Ridge National Laboratory, Oak Ridge, Tenn., July (1950), 9 pp.

Shielding theories usually express attenuation in terms of either a point source or an infinite plane isotropic source in an infinite medium. Most shielding measurements are made with a uniform disc source in a "semi-infinite" medium. Most reactors, on the other hand, are approximate cubes, cylinders, or spheres. In order to convert from one shape to another, certain geometrical manipulations are used and are demonstrated in this report.

CF-50-8-98

Blizard E P
SHIELDING OF NUCLEAR REACTORS. LECTURE V - THE ECONOMICAL DISTRIBUTION OF GAMMA AND NEUTRON ATTENUATING MATERIAL IN A REACTOR SHIELD,
Oak Ridge National Laboratory, Oak Ridge, Tenn., August 25, 1950, 8 pp.

This lecture discusses the extreme importance of weight-saving in mobile reactor shielding. It is pointed out that were it not for the production of secondary gamma rays from neutron attenuation the problem would be solved by locating all the gamma shield next to the reactor where its volume would be wrapped on the outside.

A solution to this shielding problem is presented and mathematically solved using two shielding materials: one material primarily for neutrons and the other for gammas.

CF-50-12-104

Segaser C L
HRE SHIELDING DESIGN REPORT - SUPPLEMENT,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26,
December 27, 1950, 43 pp.

This report is submitted as a supplement to CF-50-10-135 in which a proposed shielding structure was presented and analyzed from the standpoint of biological effectiveness. This report describes further precautions to reduce possible radiation hazards. Also the benefits derived from additional precautions are discussed.

A proposed system for inducing air through the HRE shielding structure is described. The requirements for this system are presented.

CF-53-2-99

Abernathy F H and Enlund H L F
HEATING BY FAST NEUTRONS IN A BARYTES CONCRETE SHIELD,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., February 11, 1953, 7 pp.

The moderation of fast neutrons in shield materials results in the loss of their energy which then appears as heat. Equations and constants are presented for calculating the heating in barytes concrete.

CF-53-7-170

Blizard E P
REACTOR LEAKAGE FOR SHIELDING CALCULATIONS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., July 24, 1953, 8 pp.

The geometry transformation from plane to spherical reactor-shield interfaces depends only on the assumption of the existence of a unique attenuation kernel for all pairs of points in space, (source at one point and detector at the other), but it applies only to surface distributions of sources. For neutron attenuation the assumption is quite good, but surface source distributions do not exist except as infinitesimals. Integrations are used to show the equivalence of imaginary surface sources to volume-distributed sources.

CF-53-10-168 (Del)

Pearce W R
ANALYSIS OF WATER ACTIVATION AND COMPONENT SHIELDING FOR THE ORNL PACKAGE REACTOR POWER PLANT,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, November 10, 1954, 23 pp. (8 refs)

The activity of primary coolant water in the ORNL Package Power Reactor is estimated for 10-Mw operation and the required thickness of concrete shielding about the steam generating compartment is specified.

Assuming a normal contaminant concentration of 2 ppm in the initial charge of coolant and 30 gallons per hour makeup of the same degree of purity, a corrosion rate of 0.05 mg/cm^2-mo, and an effective range of 10^{-5} cm for Mn^{56} recoil atoms, a concrete thickness of 4 ft is required to obtain the specified tolerance of 5.36 mrep/hr.

Shield thickness is determined solely by the magnitude of N^{16} activity and appears to be independent of the contaminant content.

CF-53-11-2

Blizard E P
THE SHIELDING OF NUCLEAR RADIATIONS. LECTURE I - INTRODUCTORY SURVEY,
Oak Ridge School of Reactor Technology, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 2, 1953, 14 pp.

This paper is a lecture covering introduction to shielding, the sources of radiation, and tolerances.

The importance of shielding is discussed in regard to the biological damage resulting from nuclear radiation.

A brief description is given of the individual radiations. These are the alpha particle, the beta ray, the gamma ray, the X-ray, and the neutron.

The radiation dose below which harmful biological effects will not be induced is called the tolerable dose, or simply the tolerance. The magnitudes of this dose, the periods over which it may be received, and maximum lifetime total dose are discussed.

CF-54-7-105

Cochran R G, et al.
REACTOR RADIATIONS THROUGH SLABS OF GRAPHITE,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, July 30, 1954, 22 pp.

Measurements have been completed to determine the attenuation of large thicknesses of graphite next to a reactor. These measurements are of interest for evaluating a graphite reflector as a shield component, and they also provide a direct comparison with LTSF determinations of the carbon removal cross section. Graphite thicknesses of 1, 2, and 3 ft were used, and the usual gamma-ray, thermal-neutron, and fast-neutron dose measurements were made behind each slab thickness. In addition, the fast-neutron spectrum (above 1.3 Mev) through 1 ft of graphite was measured.

CF-57-1-46

Claiborne H C and Fowler T B
CALCULATION OF SHIELD-INDUCED GAMMA RADIATION ESCAPING THROUGH OPENINGS IN A BIOLOGICAL SHIELD - APPLICATION TO THE HRT,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., January 11, 1957, 19 pp. (9 refs).

This report presents the derivation of equations for calculating shield-induced gamma radiation escaping through openings in a biological shield. This method of calculation is applied to the HRT and the results indicate that the contribution to the dose from induced activity in the HRT shield was around 0.1 r/hr and was insignificant in comparison to other mechanisms contributing to the escape of gamma rays through shield openings.

CF-57-2-98

Claiborne H C and Fowler T B
CALCULATION OF WALL-SCATTERED GAMMA RADIATION ESCAPING THROUGH A SHIELD OPENING - APPLICATION TO THE HRT,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., February 19, 1957, 26 pp. (3 refs).

This report discusses a simplified method developed for calculating wall-scattered gamma radiation escaping through a shield opening. The method was applied to the HRT and the results show that next to the line of sight contribution, scattering off the wall of the shield opening was the main contribution to the dose at the rear edge of the shield. Design charts are presented which give the dose as a function of the gamma source locations within the reactor cell.

CVAC-170 FZK-9-051

Jones B L, Harris J W and Kunkel W P
AIR AND GROUND SCATTERING OF COBALT-60 GAMMA RADIATION,
Convair, Division of General Dynamics Corporation, Fort Worth, Tex., Contract No. AF33(038)-21117, March 30, 1955, 38 pp. (6 refs).

Air and ground scattering of cobalt-60 gamma radiation has been experimentally investigated for source-receiver separation distances from 7.5 feet to 70 feet and for heights above ground from 9 feet to 57 feet. Light weight television antenna towers were used to support the source and detector at various heights and separation distances. One tower was used to support the detector and a 4" x 4" x 8" lead brick. The lead brick was used to attenuate the direct beam so that only scattered radiation was measured. The detector tower was mounted on a dolly, allowing the source-detector separation distance to be controlled remotely.

A second tower was used to support a cable and pulley arrangement that permitted the source height to be remotely controlled. The detector employed was an anthracene scintillation dosimeter. The anthracene crystal was mounted on an RCA-5819 photomultiplier tube from which the integrated signal current was obtained and measured. Dark current compensation and a magnetic shield were incorporated in the design. Linearity of response to radiation intensity and the effect of temperature changes on response were checked.

The experimental results show that the dose rate at the detector due to scattered radiation was negligibly affected by changes in height after a height of about 45 feet had been reached. It was concluded, therefore, that the data for heights greater than 45 feet was about equal to that which would result from air scattering alone in the absence of the ground. The raw data for heights greater than 45 feet and for separation distances greater than 35 feet closely fit a straight line plot on log-log paper. The variation of the air-scattered dose rate thus fits a straight line corresponding to a variation $1/a^n$. The best value of the exponent of a was found to be $n = 1.06 \pm 0.02$.

The effects of radiation scattering by the television antenna test rig structure were experimentally determined by taking data with and without a replica of the top section of the detector-shield tower mounted in a mirror-image position above the detector and shield. The difference in the data with and without the image structure was considered to be the correction for tower structure scattering.

CVAC-171 FZK-9-052

Bernard C H
AIR SCATTERING OF GAMMA RAYS FROM A CO^{60} SOURCE,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, August 20, 1953, 26 pp.

A 70 curie Co^{60} gamma source was used in conjunction with a nondirectional anthracene dosimeter to measure air scattering. The experimental results were then used to make a comparison study to determine the accuracy with which single scattering theory could predict dose rates. The dose rate was found to be inversely proportional to the source-detector separation distance as predicted by theory for distances between 30 ft and 70 ft. When the source-detector system is 45 ft or more above ground, the measured dose rate is almost wholly due to air scattering. This then makes available a method by which ground scattering can be determined experimentally.

CVAC-172 FZK-9-053

Bernard C H
GROUND SCATTERING OF GAMMA RAYS FROM CO^{60} SOURCE,
Convair, Division of General Dynamics Corporation, Fort Worth, Tex., Contract No. AF33(038)-21117, August 13, 1953, 31 pp.

A single scattering theory has been developed for the purpose of evaluating its use in predicting ground-scattering dose rates. When compared with experimental measurements from a Co^{60} gamma source, there is fairly good agreement when the source-detector separation distance is more than three times the height above the ground. The theory is based on Klein-Nishina relations and, since the geometry in air utilizes distances much less than the mean free path, air attenuation is neglected. The source and detector were each mounted on television antenna towers in such a manner that both the height above the ground and the separation distance could be varied through rather wide limits.

A theory based on reflection coefficient (albedo) was applied to the experimental data and the albedo calculated. The ground (ordinary soil) albedo for Co^{60} gamma rays was found to vary from about 0.02 to 0.06 as the geometry was varied, indicating that the albedo is not constant for a given material but increases as the ratio of source-detector separation to height increases. There seems to be a dependency upon the angle between the incident radiation and the ground.

CVAC-198T MR-A-336

Woodruff L V, Harris J W and Kunkel WP
AIR AND GROUND SCATTERING OF CO^{60} GAMMA RAYS IN A SHADOW SHIELD GEOMETRY,
Nuclear Physics Group, Convair, Division of General Dynamics Corp., Fort Worth, Texas, December 16, 1953, 10 pp.

This report presents preliminary results obtained to ascertain the manner in which the scattered dose rate from a Co^{60} source varies as a function of the shadow shield angle. The shadow shield employed was the container for the large Co^{60} source. An anthracene scintillation dosimeter was used to measure the scattered dose rate.

The experimental layout is shown and the results presented graphically.

CVAC-211T MR-N-5

Weller G S and Workman B J
SINGLE SCATTERING OF NEUTRONS IN AIR,
Nuclear Physics Group, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, September 17, 1954, 19 pp.

Shielding studies often require an evaluation of the radiation scattered into a detector from a distant source. This evaluation entails long and tedious calculations for each specific case. In this report an attempt has been made to set up a method whereby two of the three required integrations have been performed for the general case so that only one integration is necessary for a specific case.

CVAC-212T MR-N-1

Secrest E L
MULTIPLE SCATTERING OF NUCLEAR RADIATION,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, January 8, 1954, 23 pp.

A systemic approach to scattering calculations for point sources in infinite media has been outlined. This model classifies successive approximations to the complete scattered dose according to single collision flux, double collision flux, etc.

Numerical calculations are presented for isotropic scattering with a definite average energy loss per collision. It is shown that the single collision model can give either an underestimate or an overestimate of the scattered flux. The dependence of this effect on cross section and separation distance is demonstrated.

The calculations cover a range of separation values from 0 to 5 mean free paths (for the source energy).

CVAC-219T MR-A-318

Leonard B P, et al.
REPORT ON THE EXPERIMENTAL DATA OBTAINED WITH THE 2π SHIELD,
Convair, Division of General Dynamics Corporation, Fort Worth, Texas, January 15, 1954, 34 pp.

The necessity for performing structural scattering experiments near the ground in the initial phases of the program has lead to a search for a means of eliminating ground scattering from the results. It was thought probably that, in the case of the Co^{60} experiments, a 2π source shield might prove effective. This experiment was performed to determine the effect of placing a Co^{60} source at the center of a square lead shield 4 inches thick and 24 inches on a side. Specifically, it was desired to determine: (1) the sharpness of the reduction in dose rate at the edge of the shield (at the surface joining the shielded and the unshielded hemispheres), (2) the dose rate in the shielded hemisphere, and (3) the ratio of the dose rate due to the back scattered and the direct radiation at various positions in the unshielded hemisphere.

The reduction in dose rate at the edge of the shield was observed to be extremely sharp, going from a maximum to background in slightly more than 2 degrees. The dose rates recorded at several positions in the shielded hemisphere were at the background level. The ratio of the dose rates due to radiation scattered from about 1.5% to slightly less than 5%.

CVAC-243T FZK-9-082

Perkins J F
A MONTE CARLO CALCULATION OF SCATTERING OF GAMMA RAYS BY CONCRETE AND ALUMINUM,
Nuclear Physics Group, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, July 9, 1954, 65 pp. (11 refs)

The number and energy gamma-ray albedos of a material of Z_{eff} = 13, which includes both concrete and aluminum, and the spatial and spectral distribution of the scattered

radiation have been calculated using a random sampling technique. Incident angles of 0^{o}, 45^{o}, 60^{o}, and 80^{o} and a number of incident energies between 0.66 and 6 Mev were treated, the only interaction processes considered being Compton scattering and photo-electric absorption. The calculations were performed on an IBM 701 computer, the requisite speed dictating operation in a fixed point.

The portions of the albedos arising from the first scattering and from all subsequent scatterings have been calculated separately with the result that the first scattering usually contributes considerably less than half of the total; this holds for both number and energy albedos. The fractional probable error in the portion of the albedo arising from the first scattering is larger than in the other portion and, since the contribution from the first scattering is fairly easy to treat deterministically, it is felt that the most significant aspect of the present results is that concerned with the multiple-scattered component.

The spatial distribution of the multiple-scattered component was found to be definitely anisotropic; in fact for small and moderate incident angles the distributions of the number dose and the energy dose per unit emergent solid angle are each rather adequately fitted by a factor proportional to the cosine of the normal angle of emergence.

Both the single- and multiple-scattered components were found to increase with the angle of incidence.

The spectra peak around 150-250 kev and in some cases have a second peak at higher energy; such secondary peaks move upward in energy and increase in importance as the angle of incidence increases. The average energy of the emergent photons varies from 0.33 to 1.4 $m_{o}c^{2}$. For the multiple-scattered component the average energy varies from 0.30 to 0.93 $m_{o}c^{2}$.

The variation with azimuthal angle peaks in the forward direction. This results largely from the single-scattered component, becoming more pronounced at higher angles of incidence.

Buildup factors have been calculated for 2 $m_{o}c^{2}$ gammas normally incident on aluminum slabs of 2 and 4 mean free path thickness.

CVAC-245T MR-N-25

Feinauer Earl
A MONTE CARLO EVALUATION OF SINGLE SCATTERING INTEGRALS,
Nuclear Physics Group, Convair, Division of General Dynamics Corporation, Fort Worth, Tex., March 19, 1954, 23 pp. (2 refs).

This study was conducted to investigate the applicability of Monte Carlo sampling techniques to theoretical calculations of gamma and neutron scattering. The single scattering of gamma rays in air was evaluated by Monte Carlo techniques, using a table of random numbers to determine the points at which evaluations of the integrand were made.

The investigation gave a value of 0.7863 mr/hr/curie for the air-scattered dose for N = 126 which is within 3.24% of the 0.7616 mr/hr/curie reported in MR-A-319. A complete tabulation of the results may be found in Part III of this report.

CVAC-251T MR-A-342

Weller G S and Workman B J
ANGULAR NEUTRON SCATTERING CROSS SECTIONS FOR AIR,
Nuclear Physics Group, Convair, Division of General Dynamics Corp., Fort Worth, Tex., August 24, 1954, 12 pp.

In many cases the scattering of neutrons by a medium results in an important contribution to the energy received at a point due to a given neutron source. Since the medium often concerned is air, this report presents results from calculating the angular elastic scattering cross section in this medium for neutrons of various energies.

The calculations are based on an average air nucleus, the radius of which was calculated from the expression: $R = 1.5 \times 10^{-13} A^{1/3}$ cms, where A is a weighted mean atomic weight for air.

CVAC-252T MR-A-334

Weller G S
CALCULATION OF THE MINIMUM NEUTRON SHIELDING WEIGHT REQUIRED FOR A SPHERE USING TWO MATERIALS,
Nuclear Physics Group, Convair, Division of General Dynamics Corp., Fort Worth, Tex., November 25, 1954, 21 pp.

For a given total attenuation using two materials which differ in density and attenuation factors but have similar attenuation characteristics, the overall neutron shield weight is less than that of a single material. This is due to the fact that a heavy material with high attenuation characteristics is best for minimum weight close to the reactor core, whereas a light material with a small attenuation factor effects more weight savings as the shield thickness increases.

The purpose of this report is to calculate and tabulate in graphical form the optimum thicknesses for materials of various densities and attenuation factors to give a minimum spherical shield weight.

The method of calculation is presented.

CVAC-258T MR-A-319

Billings J J
SPACE DISTRIBUTION OF GAMMA FLUX - THE SINGLE SCATTERED COMPONENT,
Nuclear Physics Group, Convair, Division of General Dynamics Corporation, Fort Worth, Texas, October 12, 1953, 15 pp.

Both theoretical and experimental work indicate that scattering of gammas is of great importance in shield design. The thickness of the shield should vary depending upon the distribution of the air-scattered flux falling upon the shield. Shield design would be facilitated if this flux distribution were known. It is the purpose of this report to present the distribution of the single-scattered component, the contribution likely to predominate at distances of interest in shielding calculations. Results for four energies are presented in the expectation that these four energies can be made to represent an actual energy spectrum.

CVAC-266T MR-N-54

Shelton R D, Perkins J F and Feinauer Earl
GROUND SCATTERED DOSE CALCULATIONS USING A MONTE CARLO ALBEDO,
Nuclear Physics Group, Convair, Division of General Dynamics, Fort Worth, Texas,
September 14, 1954, 17 pp.

An approximate analytic expression for the multiple scattering predicted by the Monte Carlo albedo calculations for Co^{60} has been obtained in a form readily applicable to ground scattering calculations for various source-detector geometries. It is seen that this expression, which contains the assumption that the ground scattering can be described as a surface effect, does not agree with the albedo assumptions usually made for the purpose of calculating ground-scattered dose.

The expression for the multiple scattered dose, when added to the known expression for the single-scattered dose, should permit a calculation of the total ground-scattered dose which is more accurate than calculations assuming single scattering only or single scattering plus the usual albedo assumptions.

EDI-19

Aitken P B
CORRECTION FOR BUILDUP FACTORS FOR LEAD AND STEEL SHIELDING FOR 1 MEV AND 1.3 MEV γ RADIATION, Available in the Sandia Corporation Library, 6 pp.

In order to visualize the effect of the correction due to buildup, and for convenient reference, shielding values for lead and steel for two common energy values - 1 Mev and 2 Mev - have been calculated and plotted graphically, together with values uncorrected for buildup.

ER-8018

Byrum Barney L and Biggerstaff John A
NUCLEAR RADIATION HEATING,
The Glenn L. Martin Company, Baltimore 3, Md., January (1956), 45 pp. (9 refs).

The problem of heat generation in a reactor gamma shielding material is defined, and a technique that is adequate for establishing preliminary design requirements is developed. The results are presented in a manner facilitating application by the designer of the best pertinent experimental data which may be made available from time to time.

The salient simplifying assumptions are:

1. Geometry may be represented by a plane slab (gamma shielding) of finite thickness and infinite extent bounded by a reactor core region and a neutron shielding region.
2. Neutron fluxes in the slab follow simple exponential distributions (thermalization of fast neutrons is not considered).
3. Gamma rays which leave the slab do not return.
4. Neutrons scattered from the plane slab region into the reactor core region do not return to the slab (albedo of source region is zero for neutrons).

5. Albedo of the neutron shielding region is known for neutrons.
6. Primary neutron and gamma-ray currents incident upon the slab are known.
7. Certain nuclear parameters (discussed in the text) are known for the case of interest.
8. Annihilation photons are absorbed near their points of origin.
9. First order corrections for multiple Compton scatterings are sufficient.

Although considered adequate for preliminary design, the simple exponential function (representing the volumetric source strength of gamma rays arising in the shield) may be modified, when warranted, on the basis of approximate experimental data.

As an example, the heat generation distribution in a slab of iron 6 inches thick is estimated for a given set of parameters.

FRDC/P-87 SWP/P-13

Bonsall W
SUMMARY OF CALCULATIONS ON THE FAST REACTOR SHIELDS,
Division of Atomic Energy (Production), Risley, Lancashire, England, January 12, 1955, 5 pp.

This is a brief report which presents a summary of calculations on the fast reactor shields. The topics briefly presented are data on which the calculations are based: shield thickness and results.

HW-26574

Brown R E
HEAVY AGGREGATE INVESTIGATION,
Radiological Sciences Department, Hanford Works, Richland, Wash., December 19, 1952, 11 pp.

This report is the result of a survey of minerals and mineral products that might be used and available for high-density concrete aggregate for reactor construction. Materials used in the past and those planned for future construction are discussed and are probably the most satisfactory. This report also suggests new and local sources of aggregate material.

HW-55372

NEUTRON ATTENUATION IN MAGNETITE CONCRETE HEATED TO 200°C,
Hanford Works, Richland, Washington, March 25, 1958, 14 pp.

This report is a continuation of the previously described program (Wood, D. E., Neutron Attenuation in Magnetite Concrete Heated to 100°C, HW-53395, December 1957) to determine attenuation properties of heated concrete. Curves are included which show the attenuation traverses for heated and unheated magnetite concrete. Horizontal traverses were also taken and are presented in curve form. Several slabs were weighed at different stages of the test and these data are in table form. Slab temperature was recorded by installing thermocouples between each.

HW-56195

Clark R G
RADIATION DAMAGE TO CONCRETE,
Hanford Atomic Products Operation, Richland, Wash., Contract No. W-(31-109)-Eng-52, March 31, 1958, 23 pp. (111 refs).

The question of radiation damage to concrete is of importance. This report represents a compilation of significant results to date, and also a current bibliography on the subject.

Data are available for conditions of flux up to 2×10^{19} nvt (thermal) and temperatures of 120°C. Under these conditions, radiation damage to concrete is apparently insignificant. All effects on concrete due to radiation per se were too slight to reliably measure because of the gross effects from the increased temperatures during exposure.

IDO-16011

McMurry H L
SHIELDING REQUIREMENTS FOR EXPERIMENTS ANL-2 AND KAPL-2,
Technical Branch, Atomic Energy Div., Phillips Petroleum Co., Idaho Falls, Idaho, April 1, 1952, 9 pp. (11 refs).

Several experiments proposed for the MTR will involve irradiation of U^{235} bearing materials in regions of high thermal flux. These experiments will have to be removed from the pile in the lead coffin and some of them may require examination in the proposed hot cave. In order to know whether they can be handled safely in these facilities, estimates of the gamma-ray intensities transmitted by the coffin and cave are necessary. Calculations are reported here for the experiments ANL 2 and KAPL 2. Until further calculations are available for other experiments these results will serve as guides to what can be expected in experiments with similar compositions.

IDO-16073

Fast E, Byrom J P and McCaslin J W
A SURVEY OF THE MATERIALS TESTING REACTOR SHIELD,
Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho, Contract No. AT(10-1)-205, May 27, 1953, 33 pp.

A detailed survey of the MTR shield to determine its adequacy from a health physics point of view has been completed. The survey was made with X-ray film and with survey instruments. The bulk shield in general shows no radiation leaks attributable to faulty construction. However, beam intensities from the experimental plugs are greater than anticipated. Revisions were made in the keys for orienting the experimental plugs, and in the outer shielding plugs to reduce these beam intensities to permissible values. No excess neutron intensities were found except at the thermal column. The slow neutron flux was originally at biological maximum permissible during full power operation, but one-fourth inch of boral plate has effectively reduced this by a factor of roughly 10^3. Gamma intensities at this point remain at near maximum permissible levels (MPL = 7.5 mr/hr)

The shield of the sub-pile room appears to be considerably better than the designers anticipated. A maximum intensity of 300 mr/hr was measured in the basement during the discharge of a fuel assembly through the sub-pile room. During normal operation, a reading of 1 to 2 mr/hr is observed in general in the sub-pile room.

IDO-16414

Kobold V C
HEAT GENERATION WITHIN THE THERMAL SHIELDS AND VESSEL WALL OF THE SPERT-III REACTOR,
Phillips Petroleum Co., Atomic Energy Div., Idaho Falls, Idaho, Contract No. AT(10-1)-205, March 1, 1958, 22 pp. (19 refs).

This report presents calculations of heat generation within the thermal shields and the vessel wall of the SPERT-III Reactor. The calculations were performed to check an earlier estimate and assure adequacy of the shield design prior to installation in the reactor. The data are derived from an evaluation of the heat generated by the absorption of gamma photons from fission and from neutron capture within the core, reflector and shield regions.

IDO-24003

BARYTES AGGREGATE CONCRETE APPLIED TO REACTOR SHIELDING,
Chemical Plants Division, Blaw-Knox Construction Co., Contract No. AT(10-1)-2, July (1952), 220 pp. (16 refs).

Beginning in February of 1950 Chemical Plants Division of Blaw-Knox Construction Company, then under contract with the USAEC to design the reactor and auxiliary facilities for the Material Testing Reactor at Arco, Idaho, collaborated with ORNL in the redesign of the biological shield.

Previous practice, in designs for biological shielding, utilized lead, steel, ordinary concrete and heavy concrete made with processed iron or steel as the coarse aggregate. On the basis of previous limited use and tests of concrete made with natural ores as aggregate by ORNL, it was decided that the biological shield for the MTR should be designed using a concrete containing barytes ore as the aggregate.

This report contains detailed descriptions of (1) methods used for selection, handling, and processing of the ore, (2) test programs conducted to determine the design of the mix for structural properties and density, and (3) actual field operations of mixing and placing three types of concrete made with barytes aggregate.

Tests conducted prior to actual placing proved that barytes concrete had structural properties nearly equal to stone aggregate concrete (except for weathering), a density ranging between 218 and 226 pounds per cubic foot, and that it could be mixed and placed at a cost comparable with placing the amount of ordinary concrete required for equivalent biological shielding. The most variable factor affecting the cost was the distance of the ore deposit from the site.

MDDC-806

Goldberger Marvin L
THE SHIELDING OF NUCLEAR REACTORS,
Argonne National Laboratory, Lemont, Ill., (1947), 9 pp. (2 refs).

A summary of the problems connected with the protection of personnel from the radiation coming from a pile is given. The tolerance doses due to the various radiations are computed and methods are given for estimating the thickness of protective shields in certain practical cases.

NAA-SR-880

Henrie J O
MAGNETITE IRON ORE CONCRETE,
North American Aviation, Inc., Downey, Calif., Contract No. AT-(11-1)-Gen-8, January 26, 1954, 21 pp.

Crushing and handling of the magnetite iron ore which was used as the aggregate for a dense shielding concrete is discussed. The physical properties and costs of the concrete are compared to those of other concretes. The mix used has a compressive strength of 4,000 psi in 10 days. The methods used in fabricating shielding blocks are described. Recommendations for producing a low cost, relatively high density shielding concrete are made. The shielding blocks used in the hot cell at North American Aviation, Inc. (9 x 9 x 18 inches nominal) have a density of 3.7 gm/cm^2 or 230 lb/ft^3 and cost $163.50 per cubic yard. The dimensions of the blocks are quite uniform, having a standard deviation of approximately 0.015 inch.

NDA-2015-93

Certaine J and Goldstein H
FINAL REPORT ON SHIELDING CONTRACT FOR 1956,
Nuclear Development Corporation of America, White Plains, N. Y., Contract No. AT(30-1)-862, December 31, 1956, 4 pp.

This report is a summary of the unclassified activities of NDA in connection with Contract AT(30-1)-862, Modification No. 31, during the year 1956. The year's efforts were directed along four lines: (1) shielding needs for neutron cross-section data, (2) revision of unclassified publication titled "Shielding of Nuclear Reactors." (3) modification and extension of the Univac codes for studying penetration of neutrons, and (4) calculation of penetrations of neutrons in lithium, lithium compounds, water, homogeneous lead-water, boron, and B^{10}.

Six papers were published during the year and two more were published shortly afterwards. The titles of these publications are:

NDA 15C-61	A Solution of the Neutron Transport Equation, Part III
NDA 15C-87	Operating Instruction for NVPAK
NDA 15C-88	Trip Report of NBS Neutron Age Meeting - J. Certaine
NDA 15C-89	Trip Report of NBS Neutron Age Meeting - P. Mittelman
NDA 15C-91	Final Report on Shielding Contract for 1955
NDA 2015-92	Addition of Inelastic Scattering to the Univac Movement Calculations

NDA 2015-94 Age of Neutrons in Water at the Indium Resonance
NDA 2015-95 Operating Instructions for Inelastic Scattering Calculations.

NESC-57-29

Alexander Lloyd G
THE INTEGRAL SPECTRUM METHOD FOR GAMMA-HEATING CALCULATIONS IN NUCLEAR REACTORS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Published by The American Society of Mechanical Engineers, for the Second Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 13 pp. (9 refs).

The attenuation law for the "integral" beam is derived for the straight-ahead-scattering model, and the mean energy absorption coefficient is defined. The general gamma-heating equation is then formulated and applied to a variety of geometries, including self-shielded cylinders and plates, slabs with nonuniform volume distribution of sources, etc. Numerical examples are given.

NESC-57-51

Glen H M
MATERIALS OF BIOLOGICAL SHIELDING,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Published by The American Society of Mechanical Engineers, for the Second Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 10 pp. (7 refs).

This paper discusses major design requirements for effective biological shielding of (a) hot cells and caves (b) nuclear reactors, including a comprehensive review of the properties. Characteristics, costs and other considerations for several types of metallic, organic and concrete shields. Particular attention is given to high density and hydrogeneous concrete mix ratios and special placement and curing problems associated with various shield designs.

NP-3390

Secrest E L
NUCLEAR SHIELDING STUDIES, A QUADRATURE METHOD FOR COMPUTING NEUTRON DISTRIBUTIONS IN TWO DIMENSIONS,
Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Mass., July 16, 1951, 112 pp. (12 refs).

The transport equation governs the scattering and absorption of multiply scattered neutrons during passage through matter. Present techniques do not allow exact solution of the equation except for a very few special cases. Elementary diffusion theory has proved quite useful in some instances, but for a large number of problems this theory does not give results of sufficient accuracy. Several methods have been developed in the past which give better solutions for certain classes of problems, principally for those problems involving only one-dimensional space variation.

It has been the purpose of this work to investigate the possibility of arriving at a method which can be used for problems in two dimensions. Although the transport equation has not been solved exactly in two dimensions, an iterative method has been developed, which, when combined with a quadrature approximation, allows derivation of approximate solutions of the transport equation.

An integral relation for the neutron distribution function has been set up in a form suitable for an iterative solution. In order to carry out the iteration the assumption has been made that the neutron distribution at a given point in space can be represented by neutron flow along a finite number of streamlines. This assumption greatly simplifies the performance of the iterative integrals.

Since the method is expected to be most useful when the problem under consideration differs but slightly from a similar problem with a known solution, several such examples have been worked out. More specifically, the effect of introducing a void in the form of a slit into a semi-infinite medium (either capturing or noncapturing, infinite or finite) has been considered in some detail. This alteration of geometry effectively transforms the one-dimensional problem to a two-dimensional problem.

It has been found that the iterative solution is satisfactory in boundary regions only if a large number of quadrature angles are chosen for the iterative integrals. The solution in such boundary regions does not seem to require a large number of iterations. On the other hand, in regions far removed from the source of perturbation, a large number of iterations is necessary for satisfactory results, while a large number of quadrature angles does not seem to be necessary.

Although the investigation has been carried out primarily for the one-velocity form of the transport equation, a procedure has been indicated whereby energy dependence of the distribution can be included to a limited extent.

NP-6335 (Vol.1)

PROCEEDINGS OF THE SHIELDING SYMPOSIUM,
The Naval Radiological Defense Laboratory, San Francisco 24, Calif., October 17-19, 1956, 266 pp.

A resume' of the papers presented at the shielding symposium is as follows:

Aspects of Gamma-Ray Penetration Theory Relevant to Shielding Problems.
Effects of Boundaries and Inhomogeneities on the Penetration of Gamma Radiation.
Some Theoretical Methods and Results in Gamma-Ray and Neutron Shielding.
Radioactive Decay Characteristics of Fallout and Gamma Radiation Fields.
Brief Summary of Gamma Radiation Spectra from Residual Radiation Sources.
Shielding Properties of Naval Buildings.
Shielding by Military Structures.
Fallout Countermeasures for AEC Installations.
Fission Product Gamma-Ray Spectra for Short Times after Fission.
Basis for Determining Shielding from Weapons Radiation.
Pulse-Height Spectra from Gamma-Ray Slab Penetration Experiments.
Use of Locally Available Material for Argonne Low Power Reactor (ALPR) Shield.
Gamma Intensity-Time Instrumentation for CASTLE Shielding Studies.
Monte Carlo Shielding Calculations.

NRL-4581

Beach L A, Theus R B and Faust W R
PENETRATION OF Na^{24} RADIATION THROUGH H_2O AND Hg,
Naval Research Laboratory, Washington, D. C., July 26, 1955, 4 pp.

The dose rate as a function of penetration distance was measured for a point isotropic Na^{24} γ-ray source in water and in mercury. The experimental results agreed with dose rates predicted by the moment method calculations of NDA Report No. 15C-41.

NRL-4673

Podgor S and Beach L A
MONTE CARLO REACTOR CALCULATION,
Naval Research Laboratory, Washington, D. C., December 9, 1955, 8 pp. (8 refs).

The Monte Carlo method has been used to estimate the slowing down of fast neutrons in a spherical homogeneous mixture of U^{235} and H_2O. The estimated probability distribution of thermalization was compared favorably with those of other calculational methods and with experimental measurements. These probability distributions were used to calculate the critical ratio of U^{235} to H_2O for both bare and reflected core reactors.

NYO-3075 NDA-15C-41

Goldstein Herbert and Wilkins J Ernest, Jr.
CALCULATIONS OF THE PENETRATION OF GAMMA RAYS,
Nuclear Development Associates, Inc., White Plains, New York, Contract No. AT(30-1)-862, June 30, 1954, 196 pp. (49 refs).

An extensive series of calculations on the penetration of gamma rays in infinite homogeneous media has been made using the "moments method" introduced by Spencer and Fano. Spectra of scattered photons, due to monoenergetic sources ranging in energy from 0.5 Mev to 10 Mev, were obtained at distances up to 20 mean-free-path lengths in eight materials whose atomic numbers varied from 0 to 92. Source geometries included point isotropic and plane monodirectional. The computations were performed with the aid of a high speed automatic computer, the SEAC. The choice of microscopic absorption coefficients for the calculation is discussed at length, and the data used are reproduced. Definitions are given for the quantities describing the scattered photons, and the fundamental equation governing the photon transport is derived. The "moments method" is described in detail, both as to the derivation and integration of the equations for the spatial moments of the flux, and as to the procedures for reconstructing the flux from the moments. Scattered flux spectra and buildup factors are reproduced for all the calculated problems in the form of some 140 tables and 75 graphs. Methods for extending the results to problems not calculated are described. Possible sources of error are discussed. It is concluded on the basis of internal checks, comparison with other theoretical predictions, and examination of published experiments, that the accuracy of the calculations is more than adequate for almost all practical applications.

ORNL-30

Goertzel G and Garabedian H L
A METHOD OF SOLUTION OF THE CRITICAL MASS PROBLEM FOR A THERMAL PILE WITH SLOWING DOWN PROPERTIES INDEPENDENT OF POSITION,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(35-058)-Eng-71,
June 1, 1948, 22 pp.

In this report the critical mass problem is studied for a thermal pile with slowing down properties independent of position. Up to the present time, there has been available essentially only one method for solving the critical mass problem. This method is called the "variational method" and it is limited in that it is useful only for the case that the core and reflector have the same slowing down properties, and that the method has not as yet been extended to include a cylindrical geometry. The scope of the present method referred to as the "method of harmonics," is wider than that of the "variational method" in that it can be used in a cylindrical geometry, and it is more restricted in that it does not include the case of the infinite reflector.

ORNL-144

Haines G and Way K
GRAPHS SHOWING NEUTRON CROSS SECTIONS AS FUNCTIONS OF A, Z, OR W,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn.,
November 24, 1948, 12 pp.

The accompanying graphs were prepared from the neutron cross-section data of Mon P-405, Tables of Neutron Cross Sections, dated October 1947, and Mon P-405, Supplement and Errata, dated April 1948. A, Z, and N stand for atomic number, proton number, and neutron number, respectively. References to sources of data are given on the graphs.

ORNL-401

Clark R L, Flynn J D and Clifford C E
DETERMINATION OF SHIELD REQUIREMENTS FOR A 4-INCH SQUARE STRAIGHT HOLE THROUGH THE ORNL SHIELDS,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn.,
Contract No. W-(7405)-Eng-26, November 1, 1949, 15 pp.

Measurements were made of fast and thermal neutrons, and of gamma radiation, streaming through a 4-inch square straight hole (No. 61-S) through the ORNL reactor and shield. The hole was covered with slabs of lead, paraffin, and "boroffin" (paraffin-B_2O_3 mixture) in various arrangements. The following conclusions are drawn:

1. The minimum shield thickness to reduce all radiation to 8-hour operating tolerance is 22 inches.
2. The presence of boron has a small, but worthwhile, effect on the gamma attenuation.
3. The arrangement resulting in minimum weight and cost consists of four 4-inch layers of boroffin, separated by three 2-inch layers of lead. Moving the lead further into the shield increases appreciably the production of secondary gamma radiation in the shield.

4. Nearly equal neutron shielding is required in all directions, i.e., scattering in the paraffin causes the hole to appear almost as an isotropic point source, requiring a hemispherical shield.

ORNL-1046

Meem J L and Johnson E B
A NUCLEAR PLATE CAMERA FOR FAST NEUTRON SPECTROSCOPY AT THE BULK SHIELDING FACILITY,
Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, January 16, 1952, 16 pp. (5 refs).

An intensive program of instrument development is underway at the Bulk Shielding Facility for the purpose of realizing instruments which will measure the effect of shielding materials on the neutron and gamma-ray spectra from a reactor. The development of a proton recoil counter to be used as a fast neutron spectrometer is nearing completion. Preliminary reports on this instrument are available, and a rough check on the U^{235} fission spectrum has been made.

ORNL-1217 (Rev.)

Simon A and Clifford C E
THE ATTENUATION OF NEUTRONS BY AIR DUCTS IN SHIELDS,
Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, March 8, 1954, 20 pp.

The attenuation of neutrons by air ducts in shields is considered from a simple phenomenological point of view. In Section II it will be shown that the wall scattering in a straight duct is small compared to the uncollided neutrons which have traveled directly in air from one end of the duct to the other. In Section III the attenuation due to a duct which consists of two straight sections joined at an angle 8 is considered. Finally the formula is extended to the case of any number of straight sections joined at arbitrary angles.

ORNL-1414

Gallaher R B and Kitzes A S
SUMMARY REPORT ON PORTLAND CEMENT CONCRETES FOR SHIELDING,
Reactor Experimental Engineering Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, March 2, 1953, 30 pp. (4 refs).

Portland cement concretes of medium density have been developed, using a variety of aggregates to impart specific nuclear properties to the finished product. Concretes containing 1% boron as colemanite and 8% water are described, and physical property data for various concretes are given.

Thermal conductivity for barytes concrete was found to be:

Temperature (^{o}F)	122	212	257	302	392	482
k (Btu/hr-ft-^{o}F)	0.926	0.997	1.02	0.872	0.866	0.745

The specific heat (Btu/lb-^{o}F) of barytes concrete increased linearly with temperature from 0.123 at 122^{o}F to 0.150 at 392^{o}F.

ORNL-1620

Snell A H
SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING SEPTEMBER 10, 1953,
Physics Division, Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn.,
Contract No. W-(7405)-Eng-26, December 17, 1953, 72 pp. (refs).

This report describes work performed at ORNL in the Physics Division. The subjects investigated were as follows: (1) Neutron yields just above thresholds for (pn) reactions; (2) Angular correlation measurements; (3) Magnetic scattering properties of erbium metal; (4) Nuclear polarization of Mn^{55} and Sm^{149}; (5) Measurements of the electron capture and loss cross sections for heavy ions passing through gases; (6) Pile oscillator measurement of the thermal capture cross section of thorium and time of-flight spectrometer measurements are reported for Thorium, $Nickel^{62}$, and $Technetium^{99}$; (7) Instrumentation development; (8) Bulk shielding studies; (9) A consistent reduction of the nuclear operators in the theory of beta decay to nonrelativistic form.

ORNL-1739

Tirpak E G
REPORT ON DESIGN AND PLACEMENT TECHNIQUES OF BARYTES CONCRETE FOR REACTOR BIOLOGICAL SHIELDS,
Engineering and Mechanical Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.,
Contract No. W-(7405)-Eng-26, May (1954), 22 pp. (3 refs).

This report discusses the use of barytes aggregate for use in the pouring of reactor shielding. Physical properties are given for gravel-sand, barytes-barytes, barytes-shot, and taconite-shot concretes. Three methods of placement were tested: conventional vibrated layers of grout, course aggregates, and pressure grouting. A discussion of the MTR shielding is included.

ORNL-1891

Maienschein F C, et al.
ATTENUATION BY WATER OF RADIATIONS FROM A SWIMMING POOL-TYPE REACTOR,
Bulk Shielding Facility, Applied Nuclear Physics Division, Oak Ridge National Laboratory,
P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, September 7, 1955, 11 pp.

The water attenuation of the gamma-ray dose rate and thermal-neutron flux from the Bulk Shielding Reactor (Swimming Pool Reactor) was measured out to distances of 770 and 470 cm, respectively. Beyond a distance of 200 cm from the reactor, the slopes of plots of the two measurements are similar; this results from the fact that essentially all neutrons beyond 200 cm are photoneutrons produced by gamma rays in the deuterium occurring naturally in the pool water. With the photoneutrons subtracted, the true thermal-neutron attenuation curve is exponential with a relaxation length that varies between 6 and 9 cm over a reduction of 10^{10}. From these measurements it was determined that for a 1-megawatt operation the thermal-neutron leakage flux at the reactor surface (the reactor was loaded with 28 fuel elements containing a total of 3.6 kg of U^{235} and was water-reflected) was 1.1×10^{13} neutrons/($cm^2 \cdot$ sec); the gamma-ray dose rate at the reactor surface was 8×10^7 r/hr.

ORNL-2013

Cure J W, III
NEUTRON SCATTERING,
Health Physics Division, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, January 30, 1956, 34 pp. (8 refs).

Scattered radiation reaching the point of measurement is one of the major problems of neutron dosimetry. An experiment was designed to determine the variation in neutron dose rate at a point in air with: (a) the distance between the source and the detector, and (b) the height of the source and detector above a concrete slab.

The experimental data are compared with data obtained from the albedo theory, and the results agree within the experimental error. When a conical frustum of paraffin, which reduces the direct beam of neutrons by a factor of a few thousand, was placed between the source and detector, only the scattered neutrons contributed to the dose rate. This method gives data which enables one to correct for scattered radiation. To reduce extraneous scattering material to a minimum, the detector and source were supported 5 feet below a steel bar which was suspended from two painters' scaffolds 40 feet apart and 55 feet high. The neutron source was polonium-boron (which gave neutrons with an average energy of 2.5 Mev). The dosimeter was a proportional counter, ethylene-polyethylene type, with a pulse integrator for measuring the tissue dose.

ORNL-2081-13

Thomas J T
PARAMETERS FOR TWO-GROUP ANALYSIS OF CRITICAL EXPERIMENTS WITH WATER-REFLECTED SPHERES OF UO_2F_2 AQUEOUS SOLUTIONS,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 5 pp.

From four critical measurements on spheres of three sizes containing aqueous uranium solutions are obtained a set of parameters from which various other critical spheres are calculated. These include a determination of minimum critical volume (6.291 liters for a U^{235} concentration of 537.86 g/liter) and minimum critical mass (0.790 kg of U^{235} for a U^{235} concentration of 58.81 g/liter). The parameters are not satisfactory for calculations on slabs and infinite cylinders, probably because the measured cadmium fraction varies with geometry.

ORNL-2081-18

Pratt W W, et al.
THERMAL-NEUTRON FISSION CROSS SECTIONS OF Pu^{239} AND Pu^{240},
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

By use of neutrons coming from a hole in the shield and moderator of the ORNL Graphite Reactor, measurements have been made of the relative fission cross sections of Pu^{239} and Pu^{240} compared with the cross section of U^{235}. The results, after correction for the neutron spectrum to give cross sections for neutrons of 2200 m/sec, are $o^{49} = 715 \pm 15$ barns and $o^{40} = 3.7 \pm 8$ barns. A value of $o^{25} = 580 \pm 8$ barns was used to determine the results.

ORNL-2081-22

Nelson M L
REFLECTOR SAVINGS METHOD FOR ESTIMATING FLUXES IN A FULLY REFLECTED REACTOR,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

The group equations for a fully reflected reactor have not been satisfactorily solved, except in one dimension, owing to the nonseparability of the flux. An iterative scheme is described which converges to what is presumed to be a good approximation to the criticality and flux in the reflected reactor. This scheme has been programmed for use with the Oracle three-group, three-region code and may be applied to a fully reflected cylinder or parallelepiped.

ORNL-2081-26

Dresner L
CALCULATION OF NEUTRON RADIATIVE CAPTURE CROSS SECTIONS,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 3 pp.

Several methods of calculating radiative capture cross sections are compared, and numerical results are given for U^{238}. The importance of neutron angular moments higher than zero is found to be large at quite low energies.

ORNL-2081-27

Kinney W E and Heilborn G
THE ORACLE THREE-GROUP, THREE-REGION REACTOR CODE,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

Improvements have been made in the Oracle three-group, three-region reactor code. Some of these take advantage of new features of the Oracle, such as the curve plotter.

ORNL-2081-28

Kinney W E, et al.
MULTIGROUP CALCULATIONS FOR A MULTIREGION REACTOR,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 7 pp.

A multigroup, multiregion reactor code known as "Corn Pone" is under development. Equations resulting from a consistent P_1 approximation to the Boltzmann equation are incorporated in the code. Hydrogen slowing down is treated exactly, while a variety of approximate slowing-down kernels for the heavier elements are available.

ORNL-2081-29

Bate R R, et al.
ORACLE MASTER CROSS-SECTION TAPE,

Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

A master cross-section tape is being prepared for use with the various reactor programs on the Oracle. Cross sections which have not been experimentally determined will be estimated by use of current nuclear models. Auxiliary routines for this purpose are being prepared.

ORNL-2081-30

Bate R R, et al.
MONTE CARLO MASTER CROSS-SECTION TAPE,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

This Monte Carlo tape has greater cross-section detail for a lesser number of elements than the master cross-section tape. It is specifically tailored with regard to fast access and rapid use in Monte Carlo problems.

ORNL-2081-31

Bate R R and LaVerne M E
A PROGRAM COMPILER FOR THE ORACLE,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 3 pp.

The "Compiler" is an Oracle routine which is capable of integrating standard subroutines into a more general code. A routine of this sort has proved to be a valuable aid to programmers. A brief description of the Compiler is presented.

ORNL-2081-32

Coveyou R R
MONTE CARLO CALCULATION OF NEUTRON AGE IN WATER,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

A Monte Carlo code has been prepared for the Oracle to compute neutron ages in mixtures. The age of fission neutrons to indium resonance in water has been computed to be 25.17 ± 0.27 cm^2, which is in agreement with previous calculations and in the usual disagreement with experiment.

ORNL-2081-33

Marable J H
NUMERICAL INTEGRATION OF THE ONE-VELOCITY BOLTZMANN EQUATION,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

A program for solution of the one-velocity transport equation has been coded for the Oracle. Numerical integrations are performed over an arbitrary number of space points and up to 20 regions of solid angle as determined by the neutron direction. The code, at present, applies only to a single region.

ORNL-2081-34

Welton T A and Biedenharn L C
SOME REMARKS ON THE SLOWING DOWN OF NEUTRONS IN HYDROGEN,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

The predictions of the Goertzel-Selengut theory for the age in pure hydrogen are compared with the exact values obtained from the P_1 equations. These results are obtained for both the second moment of the flux density and the second moment of the slowing-down density. Numerical results are given for constant cross sections and for the experimental value of Σ_H.

ORNL-2081-35

Simon A
NEUTRON SLOWING DOWN BY HYDROGEN IN THE CONSISTENT P_1 APPROXIMATION,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 2 pp.

Two analytical solutions for the flux, slowing-down density, and age are derived in the consistent P_1 approximation to the Boltzmann equation. One solution is for pure, nonabsorbing hydrogen with a 1/v scattering cross section. The other is for all cross sections constant, with the heavy elements assumed to have infinite mass. These results are compared with the corresponding predictions of the Goertzel-Selengut theory, and a tentative explanation of the gross behavior is advanced.

ORNL-2081-36

Blosser T V
ATTENUATION BY WATER OF THE FAST-NEUTRON DOSE RATE FROM THE BSR,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 3 pp.

The fast-neutron dose rate in water at distances up to 180 cm from the BSR has been measured.

ORNL-2081-38

Miller J M
RADIATION ATTENUATION CHARACTERISTICS OF STRUCTURAL CONCRETE,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956,
Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 6 pp.

Since the shields of many stationary reactors will probably be made of concrete, a series of experiments has been initiated at the LTSF to measure the attenuation by concrete of radiation from a fission source. A fast-neutron removal attenuation coefficient (Σ_R/ρ) of 3.7×10^{-2} cm^2/g was calculated and was in good agreement with a value of $(3.6 \pm 0.2) \times 10^{-2}$ cm^2/g obtained by taking the sum of the products of the percent by weight of each element (obtained by chemical analysis) and the mass attenuation coefficient of the element.

ORNL-2081-41

Trubey D K and Chapman G T
EFFECTIVE NEUTRON REMOVAL CROSS SECTIONS OF CARBON AND OXYGEN IN CONTINUOUS MEDIA,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

Thermal-neutron flux measurements at the LTSF in media of water, oil, and a sugar-water solution have been used to calculate the neutron removal cross sections of carbon and oxygen distributed in continuous media. The values were 0.72 ± 0.05 barn for carbon and 0.92 ± 0.05 barn for oxygen.

ORNL-2081-44

Peelle R W, et al.
ENERGY AND ANGULAR DISTRIBUTION OF GAMMA RADIATION FROM A Co^{60} SOURCE AFTER DIFFUSION THROUGH MANY MEAN FREE PATHS OF WATER,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 10 pp.

Measurements have been made of the energy and angle spectra of the photon energy flux resulting from 1.17- and 1.33-Mev gamma rays from a point source after diffusion in an infinite water medium. The two sources used had strengths of 100 curies and 195 mc, respectively. Spectral measurements were made with a Compton spectrometer having a peak-to-total ratio of 0.7 and a resolution of 14% (full width at half maximum) for 1.12-Mev photons. The resulting energy and angle spectra of the energy flux are compared, after integration over angle, with calculated results which have been obtained by the "moments method."

12

ORNL-2081-45

Zerby C D
ENERGY AND ANGULAR DISTRIBUTION OF AIR-SCATTERED NEUTRONS FROM A MONOENERGETIC SOURCE,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 1 p.

A calculation of the energy and angular flux distribution of air-scattered neutrons is being made by using the Monte Carlo method. The source of neutrons can be taken as an isotropic point source, or a unit surface source, located in a sphere. The coding for calculation on the Oracle is near completion.

ORNL-2081-46

Auslender S
ENERGY ABSORPTION RESULTING FROM GAMMA RADIATION INCIDENT ON A MULTI-REGION SHIELD WITH SLAB GEOMETRY,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 5 pp.

The code of a Monte Carlo calculation of energy penetration and deposition resulting from transport gamma radiation in a shield of slab geometry has been used in a parametric study of a two-region lead-water shield. For the study the radiation was

1-Mev gamma rays incident on the slab at 0°, 60°, 70° 32', and 75° 31'. Results of the calculation are presented.

ORNL-2081-47

Auslender S
MONTE CARLO STUDY OF THE GAMMA-RAY ENERGY FLUX, DOSE RATE, AND BUILDUP FACTORS IN A LEAD-WATER SLAB SHIELD OF FINITE THICKNESS,
Applied Nuclear Physics Division Annual Report for Period Ending September 10, 1956, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn., November 20, 1956, 4 pp.

The gamma-ray energy flux, dose rate, and buildup factors in a lead-water shield of finite thickness have been calculated by a Monte Carlo method for 1-, 3-, and 6-Mev photons incident on the slab both along a normal and at an angle of 60 deg. The results are compared with those obtained by use of the "moments method" for monoenergetic, plane monodirectional sources normally incident upon a semi-infinite, homogeneous medium. The calculations for lead agree reasonably well for the first few relaxation lengths, where the effects stemming from the dissimilarity of the slabs should be least.

ORNL-2193

Blizard E P and Miller J M
RADIATION ATTENUATION CHARACTERISTICS OF STRUCTURAL CONCRETE,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, August 29, 1958, 50 pp. (refs).

An experiment was performed at the Lid Tank Shielding Facility to determine the dependence of the neutron attenuation of a structural concrete shield on the amount and placement of water hydrogen throughout the shield. It was found that a 7 wt% water content is adequate to insure that intermediate-energy neutrons are quickly slowed down to thermal energy, at which energy they are easily captured. A greater water content improves the over-all neutron attenuation according to the removal cross-section theory. In addition to the investigation of the neutron attenuation, the measured gamma-ray attenuation was compared with the predicted gamma-ray attenuation obtained in a calculation using buildup factors determined by the moments method. The two values were in good agreement.

ORNL-2389-3

Greene F N, Fink C R and Price W E
DETERMINATION OF THE POWER OF THE TOWER SHIELDING REACTOR,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (3 refs)

Calorimetric experiments to determine the power of the TSF reactor were conducted weekly during March and bimonthly thereafter in order to collect sufficient data for a statistical analysis of the results. The results, when plotted with previous data taken at six-month intervals, indicate a trend toward increasing power with time. Thermal-neutron flux measurements on the center line of one fuel element during calorimetric experiments disclosed a shift in power distribution effecting an increase in total power for the element.

ORNL-2389-18

Dresner L and Simon A
SOME ANALYTICAL SOLUTIONS OF THE SLOWING-DOWN PROBLEMS IN HYDROGEN,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (6 refs).

Analytic solutions for the slowing-down density in the P_1, B_1, and Selengut-Goertzel approximations are given for two special problems. The first is for the case in which all cross sections are constant, with the heavy elements assumed to have infinite mass. The second is for pure, nonabsorbing hydrogen with a v^3 scattering cross section. The results are discussed.

ORNL-2389-19

Dresner L
EFFECT OF FLUCTUATIONS IN THE WIDTHS ON NEUTRON REACTION CROSS SECTIONS,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp. (7 refs).

The effect of fluctuations in the widths on reaction cross sections is discussed. When the widths are distributed in chi-squared distributions, this effect can be expressed in terms of a single, infinite integral. The integral is evaluated explicitly in some simple cases. A Monte Carlo machine code for evaluating the integral in general is described.

ORNL-2389-28

Lustig H, Goldstein H and Kalos M H
COMPILATION OF NEUTRON CROSS SECTIONS OF NITROGEN AND OXYGEN,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 9 pp. (25 refs).

The best information - experimental, theoretical, and educated artistic - is being used to present, in convenient form for reactor and shielding calculations, the cross sections of nitrogen and oxygen. The data for nitrogen have been gathered and are presented. The data for oxygen are not yet complete.

ORNL-2389-31

Johnson E B, Henry K M and Kington J D
STUDY OF A THIN LEAD WATER SHIELD,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge, National Laboratory, Oak Ridge, Tenn., November 26, 1957, 1 p.

Configurations of shields consisting of lead, water, and boron were studied to develop an arrangement which would alter the leakage of neutrons and gamma rays from a TSR-11 type of reactor in a desired way.

ORNL-2389-33

Otis D R
ATTENUATION OF FAST NEUTRONS FROM A FISSION SOURCE BY WATER: COMPARISON OF EXPERIMENT WITH THEORY,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (6 refs).

Several calculations of the attenuation kernel for the fast-neutron dose rate from an isotropic point fission source in water have been performed. One calculation based on LTSF experiments in which the old source plate (SP-1) was used did not agree with a calculation performed later with the "moments" method. At the time, the discrepancy could not be resolved, but the installation of the new source plate (SP-2) has allowed some differences to be explained. A new calculation based entirely on experimental data obtained with SP-2 has resulted in agreement with the moments-method calculation.

ORNL-2389-38

Auslender S and Futterer A T
SUMMARY OF MONTE CARLO CALCULATIONS OF GAMMA-RAY PENETRATIONS IN VARIOUS MULTIREGION SHIELDS WITH SLAB GEOMETRY,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 3 pp. (4 refs).

Several Monte Carlo calculations have been performed on the Oracle to determine the dose rate, energy flux, energy deposition, and, in some cases, the energy spectra in laminated shields as a function of the energy of the gamma-ray source and the angle of incidence of the gamma rays on the shield. Since it is impractical to publish all the results from these calculations in a progress report, a summary of the problems is presented along with references to the published data.

ORNL-2389-39

Bowman L A and Trubey D K
MONTE CARLO CALCULATION OF GAMMA-RAY PENETRATION OF LEAD-WATER SHIELDS,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp.

Calculations have been continued for one of the lead-water slab shield series mentioned in Sec 9.8 and extended to include additional total shield thicknesses, as well as additional initial gamma-ray energies. A total of 512 problems has now been computed in this series.

ORNL-2389-40

Trubey D K
MONTE CARLO CALCULATION OF GAMMA-RAY PENETRATION OF ALUMINUM SLABS,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 4 pp.

A Monte Carlo calculation of the energy spectrum and angular distribution of normally incident 0.662-Mev gamma rays which are transmitted through 3-, 6-, and 9-in. thick

aluminum slabs has been performed on the Oracle. Plots of the transmitted collided energy fraction are fitted with analytical expressions.

ORNL-2389-41

Zerby C D
MONTE CARLO CALCULATION OF THE ENERGY AND ANGULAR DISTRIBUTION OF AIR-SCATTERED NEUTRONS FROM A MONOENERGETIC SOURCE,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp. (3 refs).

A Monte Carlo calculation has been performed to determine the energy flux and angular distribution of air-scattered neutrons from a monodirectional beam at a source-detector separation distance of 64 ft. The source was assumed to be located on an absorbing sphere of diameter D_0, which was assigned the values of 0, which resulted in a point source, and 12 ft. Isotropic scattering in the center-of-mass system was taken as the scattering law. The source energies included in the calculations were 0.55, 1.2, 2, 3, and 5 Mev, and the angle of radiation emission from the source was considered to be 2, 15, 30, 60, 90, 135, and 180 deg. The problem was idealized in that the source-detector system was considered as suspended in an infinite body of air.

ORNL-2389-43

Goetz C A
CALCULATION OF AIR-SCATTERED NEUTRON DOSE RATES AROUND A CYLINDRICALLY SYMMETRIC SOURCE,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 1 p.

An Oracle code has been written with which the results obtained in the Monte Carlo air-scattering calculation (Secs 9.11 and 9.12) can be utilized to calculate the neutron dose rate around a cylindrically symmetric source.

ORNL-2389-44

Lynch R E, et al.
MONTE CARLO CALCULATION OF AIR-SCATTERED GAMMA RAYS,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 5 pp. (3 refs).

A Monte Carlo calculation has been performed to determine the fluxes, tissue dose rates, angular distributions, and energy spectra of multiply scattered gamma rays in air at various distances from a monoenergetic, monodirectional source. The calculation included source energies of 0.6, 1, 2, 4, 7, and 12 Mev; source beam angles of 1, 15, 30, 60, 90, 135, and 180 deg; and source-detector separation distances of 5, 10, 20, 40, 65, and 100 ft.

ORNL-2518

ATTENUATION IN WATER OF RADIATION FOR THE BULK SHIELDING REACTOR; MEASUREMENTS OF THE GAMMA-RAY DOSE RATE, FAST NEUTRON DOSE RATE, AND THERMAL NEUTRON FLUX,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-(7405)-Eng-26, July 8, 1958, (1 curve sheet)

This is a large curve sheet showing attenuation in water of radiation from the Bulk Shielding Reactor. This curve contains measurements of gamma dose rate, fast neutron dose rate, and thermal-neutron flux as a function of distance from face of the reactor.

ASTM-9-58(16)

Coppage F N
SERF MOBILE BIOLOGICAL SHIELD-CONTROL SYSTEM,
Sandia Corporation, Albuquerque, N. Mex., Contract No. AT(29-1)-789, January 27, 1958, 26 pp.

This report contains preliminary information on a proposed control and power system for the mobile biological shields of the Sandia Engineering Reactor Facility (SERF). The shields, four in number, will be divided into six doors, which will range in weight from 73 to 275 tons. This report will discuss the desired features of such a system, a proposed control system, and possible difficulties to be encountered with the system. The SERF proposal is not yet completely firm, and information on some phases of the program is limited. As a result, changes to the control and power system proposed in this report may be required. Any such changes will be described in subsequent reports.

SCTM 21-59(16)

Barcus J R
TRANSMISSION OF NEUTRONS BY CYLINDRICAL DUCTS PENETRATING RADIATION SHIELDS,
Sandia Corporation, Albuquerque, N. Mex., March 25, 1959, 18 pp. (4 refs).

After a brief introduction to elementary neutron transport theory, the problem of the transmission of neutrons by straight and bent cylindrical ducts penetrating a radiation shield is considered. The direct scattered component is treated to a first approximation using the diffusion approximation applied to the distribution of effective anisotropic sources along the duct wall. The geometric approximations are such that the method is applicable mainly to ducts with diameter-to-length ratios small compared to unity.

TID-270

SHIELDING - REPORTS FROM SESSION IV, GENERAL INFORMATION MEETING,
United States Atomic Energy Commission, Oak Ridge, Tenn., October (1949), 57 pp. (refs).

This report is a compilation of papers as concern problems associated with neutron and gamma shielding. Subjects discussed include the following: (1) The design of a

minimum weight shield; (2) Calculation of the attenuation of neutrons and gamma rays through thick layers of shields; (3) Fundamental information on shielding as concerns analysis of shields in fast neutron fields; (4) Tests of bulk shields; and (5) Shielding materials.

TID-5280(Suppl. 1)-2

Stephenson Richard
ELEMENTS OF RADIATION SHIELDING,
Department of Chemical Engineering, New York University. Paper given at Fourth Annual Symposium on Hot Laboratories and Equipment, held in Washington, D. C., September 29 and 30, 1955, 5 pp.

For those involved with the handling of radioactive materials, the shielding problem becomes that of pure gamma shielding, since the beta particles which usually accompany radioactive decay are very easily stopped. The three factors which must be considered in the design of a suitable shield for a gamma emitter are: the nature and intensity of the radiation emitted by the radioactive source, the stopping power and geometry of the shield which is used, and the biological effectiveness of the radiation which leaks through the shield into the working areas.

The problem of pure gamma shielding is fairly simple. The theory is well understood, and all necessary data for making calculations are available. At the present time there is no reason why engineers should not carry out such calculations themselves, rather than relying upon a nuclear physicist as has been common practice in the past.

TID-7532(Pt. 1)-7

Wachspress Eugene L
THIN REGIONS IN DIFFUSION THEORY CALCULATIONS,
Paper given at Reactor Control Meeting held in Los Angeles, March 6-8, 1957, Division of Reactor Development, AEC, Washington, D. C., October (1957), 1 p.

A method for determining effective cross sections for geometrically thin absorbing regions in multigroup calculations is described. The effective absorption cross section in multigroup calculations provides a smooth transition from the usual diffusion theory cross section for low absorption slabs to the $2/3\ \lambda_{tr}$ extrapolated endpoint condition for black slabs. In effect, the average flux between mesh points of the difference equation grid is related to the fluxes at the mesh points. Self-shielding effects are accounted for by material cross section rather than difference equation modification.

Application of the theory to lattice calculations is discussed, and comparisons are made with other methods for limiting cases.

UCRL-3477

Ruehle William G, Jr.
A GRAPHIC SOLUTION FOR GAMMA SHIELDING,
Radiation Laboratory, University of California, Berkeley, Calif., Contract No. W-(7405)-Eng-48, July 24, 1956, 16 pp.

An equation for calculating gamma radiation through shielding is derived, which is applicable to practical monitoring and equipment-design problems. A graphic solution of the equation is included, as well as examples of its use and tables of values for specific conditions.

WAPD-P-663

Schiff D
NEUTRON GAMMA-RAY SHIELDING CALCULATION,
Westinghouse, Atomic Power Division, May (1955), 34 pp. (2 refs).

This report describes a trial problem done by the integral network method using the original three scattering directions approximation and the collision density formulation.[1] Since that time the network method has been modified considerably, and up to the present time the flux formulation has been used with as many as ten scattering angles.[2]

The problem consisted of a plane, monodirectional neutron and gamma-ray fission source normally incident on a plane shield consisting of alternate slabs of water and iron. The water slab thickness was 1.30 cm, the iron 2.22 cm, and there were six regions altogether, the water being adjacent to the source. On either side of the shield a vacuum was assumed.

The basic quantities calculated were the neutron and gamma-ray space-energy distributions of the directional collision density. The quantities graphed in this report are the neutron and gamma-ray space-energy distributions of the scalar flux and the spatial distribution of the dose density.

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[1] WAPD-108, "Multigroup Integral Network Method," D. Schiff.

[2] WAPD-TN-513, "Numerical Solution of the Integral Transport Equation," D. Schiff and R. S. Varga.

WASH-189

Zabel C W
REPORTS TO THE AEC NUCLEAR CROSS-SECTIONS ADVISORY GROUP,
White Plains, New York, October 10 and 11, 1955, 39 pp.

This report was presented to the AEC Nuclear Cross-Sections Advisory Group for consideration at the October 10 and 11, 1955 meeting. The report is concerned with neutron cross-section measurements, and gives recent developments, changes in emphasis, and preliminary data.

WASH-192

Zabel C W
REPORTS TO THE AEC NUCLEAR CROSS-SECTIONS ADVISORY GROUP, LEMONT, ILLINOIS,
Los Alamos Scientific Laboratory, Los Alamos, N. Mex., March 18, 1957, 39 pp. (refs).

This document consists of a group of reports presented to the AEC Nuclear Cross-Sections Advisory Group for consideration at the September 24-26, 1956 meeting at Lemont, Illinois. These reports are not intended to be complete and formal reports

covering all the work of the laboratories involving neutron cross-section measurements, but rather contain an informal statement of recent developments, changes in emphasis, and preliminary data, consideration of which is important to the cross-section measurement program of the AEC.

WASH-292 (Part 3, Suppl. 1)

Meem J L and Bairbanks F B
SHIELDING THE APPR-1,
Division of Reactor Development, Washington, D.C., September (1955), 17 pp.

This report outlines the basic operating conditions of the Army Package Power Reactor. The primary and secondary shields are discussed. Small discussions are made of shielding for spent fuel elements.

WASH-292 (Part 3)-1

Flynn J D
ATTENUATION OF GAMMA-RAY DOSE RATE AND THERMAL-NEUTRON FLUX FROM THE BSR THROUGH LARGE THICKNESS OF WATER,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at: Reactor Shielding Information Meeting May 12-13, 1955, Engineer Research and Development Laboratories, Fort Belvoir, Virginia, 9 pp. (6 refs).

A swimming pool reactor depends upon water in the reactor pool to act as the radiation shield. Other reactors utilizing the same type of core use water as the initial portion of the shield. Therefore part of the basic design data needed for such reactors is the attenuation of the reactor radiations in water. Measurements of the attenuation of the gamma-ray dose rate and the thermal-neutron flux from the Bulk Shielding Reactor have now been made through greater thicknesses of water than would be required for any practical shield. Only the direct penetration of radiation is reported here, no mention being made of the possibility of activities transported through the water.

73

WASH-292 (Part 3)-2

Murray F H
SOME STRATIFIED MEDIA TRANSPORT PROBLEMS SUITABLE FOR MACHINE CALCULATIONS,
Oak Ridge National Laboratory, Oak Ridge, Tenn. Paper presented at: Reactor Shielding Information Meeting May 12-13, 1955, Engineer Research and Development Laboratories, Fort Belvoir, Virginia, 4 pp. (4 refs).

This paper presents calculations of neutron flux as a function of angle in one or more media. It is assumed that no loss in energy occurs on scattering and that absorption may be present. In Section I, formulas are derived for the Fourier transforms of the coefficients in a spherical harmonic expansion of the flux as function of the angle for arbitrary sources in an infinite medium.[1] Formulas are also derived for the coefficients of the collision density with emission in an arbitrary direction. Considerable use is made of matrix representations of rotations in space,[2] which simplify the

[1] For complete details see F. H. Murray, "Anisotropic Scattering of Neutrons in a Uniform Medium with Beam Sources," ORNL-CF-54-11-83 (Dec. 3, 1954).

[2] E. P. Wigner, "The Problem of Multiple Scattering," Phys. Rev. 94, 17 (1954).

formulas appreciably. In Section II, certain eigen-values which are roots of determinants presented in Section I are used.[3] The method of analysis consists in replacing the homogeneous transport equation by certain systems of equations for the coefficients in the spherical harmonic expansion of the flux. These solutions of the homogeneous transport equation are employed like the solutions of a homogeneous set of linear differential equations in the solution of a nonhomogeneous equation. In this manner problems of stratified media with plane, cylindrical, or spherical symmetry can be solved by digital computing machines.

[3] See also F. H. Murray, "Analysis of the Constant Velocity Transport Equation with the Aid of Eigenfunctions of the Various Media," ORNL-CF-55-5-2 (May 1955).

WASH-292 (Part 3)-5

Gamble R L
SSN571 SHIELD TEST,
Convair, Fort Worth, Texas. Paper presented at: Reactor Shielding Information Meeting May 12-13, 1955, Engineer Research and Development Laboratories, Fort Belvoir, Virginia, 3 pp.

The purpose of the testing program was to determine the effectiveness of the shield by comparing measured radiation levels with levels specified by the Navy. The testing was carried out in the following phases:

1. A gamma survey conducted at low power to locate possible gross deficiencies.
2. Surveys of fast and thermal neutrons as well as gamma radiation at high power levels.
3. Monitoring of decay of activity in lower reactor compartment.

The test on the SSN571 was a simplified version of the program at ARCO. The STR test at ARCO was devised to check the effectiveness of shield calculations and to establish relationships between theory and practice; consequently the test program was of major importance. In the ship however, the shield test was simply one of many integrated into the complete ship testing program.

WASH-292 (Part 3)-6

Shore F J and Schamberger R D
THERMAL AND FAST NEUTRON EFFECTS IN BENT DUCTS,
Brookhaven National Laboratory, Upton, N. Y. Paper presented at: Reactor Shielding Information Meeting May 12-13, 1955, Engineer Research and Development Laboratories, Fort Belvoir, Virginia, 7 pp.

In connection with the study of neutron ducts in water, it was previously reported on the transmission of straight cylinders. Some mention has also been made of bent ducts and their behavior. The present paper is concerned with additional data which have been obtained with bent ducts. Mention will be made of the dependence of the transmission on the length of the latter sections of the duct. The dependence of the transmission on the angle of the bend for both slow and fast neutrons will also be considered. In studying the region at a bend which was most efficient in scattering neutrons, data were obtained which are of some interest and will be mentioned from the practical

viewpoint of neutron trapping. Finally, some remarks will be made in connection with albedo measurements at both Brookhaven National Laboratory and Oak Ridge National Laboratory.

WASH-292 (Part 3)-7

Schamberger R D and Shore F J
CROSS SECTIONS WITH A COLLIMATED FISSION NEUTRON SOURCE,
Brookhaven National Laboratory, Upton, N.Y. Paper presented at: Reactor Shielding Information Meeting May 12-13, 1955, Engineer Research and Development Laboratories, Fort Belvoir, Virginia, 4 pp.

An attempt has been made to obtain the neutron energy spectrum which is present in these measurements by exposing nuclear emulsions to the collimated neutrons. The scanning of the plates to determine the range and orientation of the recoil protons has not yet been undertaken. Preliminary inspection indicates that the scanning is feasible.

MISCELLANEOUS

AECD-3996

Fromm L W
DECOMPOSITION OF WATER AT HIGH TEMPERATURES AND PRESSURES UNDER REACTOR IRRADIATION,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, September 16, 1949, 23 pp.

The investigation of the high temperature and pressure dissociation of water under irradiation was undertaken by the Power Pile Division of Oak Ridge National Laboratory in an effort to determine the degree of importance of the phenomenon with respect to the design of a high temperature water-cooled power reactor. Theory and past experimentation indicate that net steady-state dissociation is determined by the rates of the dissociation and recombination reactions under the imposed conditions, the dissociation rate being essentially a function of flux and the recombination rate essentially a function of temperature. A static electrically-heated autoclave and associated temperature controlling, pressure recording, filling, purging and sampling apparatus was constructed and the autoclave installed in a test hole of the X-10 reactor under an approximate thermal flux of 5×10^{11} n/cm^2-sec. Two data runs were made, one at 350°F and one at 450°F, on water with a gas phase of saturated steam. Neither run showed any significant increase in pressure throughout, and analyses of the water phase indicated very slight gas formation easily attributed to autoclave corrosion. The conclusion was reached that, under the conditions of flux and temperature of these experiments, the recombination rate is considerably higher than the dissociation rate. Several attempts were made to determine whether or not gaseous hydrogen and oxygen added to the gas phase would dissolve and enter into the recombination reaction, but inconsistent leaks in the system valving developed, rendering the data worthless. At present the valving is being rebuilt, and these experiments will be repeated. In a future experiment investigation at higher fluxes will be carried out through the replacement of the present autoclave by one incorporating an outer jacket of uranium.

Instrumentation and external valving and connections are discussed.

AECL-454 CRL-41

Cameron A G W
STELLAR EVOLUTION, NUCLEAR ASTROPHYSICS, AND NUCLEOGENESIS,
A Series of Lectures given at Purdue University, March 25 to April 5, 1957, Chalk River, Ontario, June (1957), 167 pp. (101 refs).

These lectures are concerned with the development of different kinds of stars, the nuclear reactions which can go on in their interiors, the bearings of these considerations on the chemical composition of the universe, and the origin of the elements. It is pointed out that a good case can be made for the theory that the elements have been and are being made in stellar interiors. A brief survey is included of certain fields of astronomical knowledge which are of particular concern in these lectures.

The major topics covered in these lectures are: the development of the galaxies; Hertz-sprung-Russell diagrams; physical conditions in stellar interiors; thermonuclear reaction rates; hydrogen thermonuclear reactions; stellar evolution; helium thermonuclear reactions; the abundance of the elements; neutron capture cross sections; neutron capture on slow time scale; heavy ion thermonuclear reactions; photonuclear reactions on a slow time scale; nuclear reactions in statistical equilibrium; supernova explosions; thermonuclear reactions on a fast time scale; analysis of nuclide abundances; and nuclear reactions in stellar surfaces.

AECU-3184 ERI-1943-7-23-P

Brownell L E, Nehemias J V and Bulmer J J
DESIGNS OF POTATO IRRADIATION FACILITIES,
Engineering Research Institute, University of Michigan, Ann Arbor, Michigan,
Contract No. AT-(11-1)-162, November (1954), 37 pp. (9 refs).

Potatoes are the most important vegetable food in the domestic diet. A greater tonnage of potatoes is handled than of any other vegetable produce.

This report covers effect of gamma irradiation on potatoes, cost estimates of irradiating potatoes using different sources, and design of a potato irradiation facility.

AECU-3292 KT-210

Bradley Frank W, Murray William M, Jr. and Whitehouse David R
RADIATION PROCESSING ECONOMICS,
Engineering Practice School, Massachusetts Institute of Technology, Oak Ridge, Tenn.,
Contract No. W-7405-Eng-26, May 13, 1955, 25 pp. (24 refs).

This report is the result of a literature survey conducted with the purpose of analyzing the new unit operation of irradiation from both a technical and economic viewpoint. The scope of this investigation covers the unclassified literature of beta and gamma irradiation, availability of sources, and economic considerations.

Discussed in the report is interaction of beta and gamma radiation with matter, using irradiation effects for industrial purposes, available sources of beta radiation, economic analysis of beta sources, sources of gamma radiation, and economic analysis of gamma sources.

AECU-3458

Daniel C
STATISTICS FOR ENGINEERS,
Carbide and Carbon Chemical Corporation, Engineering Development Division, Theoretical Analysis Department, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tenn.,
Contract No. W-7405-Eng-26, (1947), 88 pp. (5 refs).

Engineers are continually confronted with the problem of estimating how certain engineering equipment will behave. Many sources of information are used in forming these estimates. Physical and chemical theory, laboratory data, engineering tests, pilot-plant experiments, and plant experience in varying proportions are all regularly used.

The notes which follow are presented in the belief that more information can be obtained from engineering data than is usually thought possible. The statistical methods proposed are also instructive in that they indicate improved methods of arranging tests and experiments that will in many cases, provide more reliable information on the points under discussion.

Twenty-six books are listed as relating to the literature of statistics. Several periodicals are also listed. Sample problems are included.

AERE-C/R-1686

Amphlett C B and Warren D T
FIXATION OF ACTIVITY IN SOLID FORM BY ABSORPTION ON SOILS,
Atomic Energy Research Establishment, Harwell, Berkshire, England, June (1956),
9 pp. (10 refs).

The absorption of activity on soils, followed by firing at high temperatures, has been studied as an alternative to fixation processes involving clay minerals. Fixation on soil is as efficient as on clay. Two types of process have been investigated, one based on ion exchange, and one in which the soil is used as a base for manufacture of a ceramic product by mixing with the waste and firing. Both types of operation give high decontamination factors under suitable conditions ($\sim 10^4$ -10^5), but the second enables a higher loading to be achieved and is applicable to a much wider variety of wastes; the engineering problems associated with large-scale operation are simpler in the first case, although there is no doubt that the second system can also be scaled up if desired.

AFOSR-TN-56-334

Penner S S, Harshbarger F and Vali V
AN INTRODUCTION TO THE USE OF THE SHOCK TUBE FOR THE DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS,
California Institute of Technology, Daniel and Florence Guggenheim Jet Propulsion Center, Pasadena, Calif., June (1956), 54 pp.

The use of the shock tube for the determination of physico-chemical parameters at elevated temperatures is considered. We present first a qualitative survey of shock tube development, in which the principles and performance of various shock-tube designs are described. Next the use of optical techniques suitable for shock-tube studies is surveyed. This section is followed by a summary of representative determinations of physico-chemical parameters behind incident and reflected shock waves. Some critical remarks, relating to the use of the shock tube as a research tool for studies of processes which are important for understanding combustion reactions, are included in the discussions.

ANL-4949

McDonell W R (duPont Assigned Employee)
I. - OXIDATION OF FERROUS SULFATE IN BORIC ACID SOLUTIONS BY IRRADIATION WITH THERMAL NEUTRONS, AND
II. - OXIDATION OF FERROUS SULFATE IN LITHIUM SULFATE SOLUTIONS BY IRRADIATION WITH THERMAL NEUTRONS,

Chemistry Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, December 22, 1952, 13 pp. (15 refs).

Part I.

In the irradiation of dilute solutions of ferrous ion and boric acid in 0.8N sulfuric acid with thermal neutrons at fluxes of 10^{10} and 10^{11} n/cm^2-sec and low gamma fluxes there is found a linear relationship between the concentration of boric acid and the extent of radiation chemical oxidation of ferrous ion by the products of the $B^{10}(n, \alpha)Li^7$ nuclear reaction. Within limits of experimental error, no variation is apparent in the yield of ferric ion per unit flux in the flux range investigated.

The determination of thermal neutron fluxes of reactors by aqueous solution radiation chemical methods requires, in general, the conversion of the neutron flux to an ionizing form of radiation.

In the experiments described herein, a preliminary standardization of such a system has been carried out. Solutions of boric acid and dilute ferrous sulfate in 0.8N sulfuric acid were irradiated in the thermal column of the Argonne heavy water reactor, CP-3', and the extent of chemical oxidation of the ferrous ion was calibrated against the neutron flux, as determined by activation of gold foils.

Part II.

An experiment similar to those described in Part I has been carried out in which an aqueous solution of 0.5 mM ferrous sulfate in 0.8N sulfuric acid was irradiated with thermal neutrons in the presence of 0.546M lithium ion.

ANL-5205

McDonell William R
DECOMPOSITION OF WATER IN BORIC ACID-CADMIUM SULFATE SOLUTIONS BY REACTOR RADIATIONS,
Chemistry Division, Argonne National Laboratory, P.O. Box 299, Lemont, Ill., Contract No. W-31-109-Eng-38, January 11, 1954, 19 pp. (18 refs).

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The presence of cadmium sulfate in boric acid solutions exposed to reactor radiations has been shown to increase the amount of boric acid which such solutions may contain before water decomposition begins. This is ascribed to an increase in the gamma flux by neutron capture in the cadmium, thus enhancing the recombination of the primary decomposition products of water, hydrogen and hydrogen peroxide. In addition, cadmium sulfate has been shown to catalyze chemically the decomposition of hydrogen peroxide to oxygen, under both Co^{60} and reactor gamma radiation.

ASAE-18

Conklin David L, Gordon Jack J and Nixon S Reed
SHIP DESIGN TREND SURVEY FOR THE ATOMIC ENERGY COMMISSION MARITIME REACTORS BRANCH,
Atomic Energy Division, American Radiator and Standard Sanitary Corp., Redwood City, Calif., Contract No. AT-(04-3)-109, June 13, 1957, 22 pp.

The American-Standard Atomic Energy Division, acting as technical consultant for the Atomic Energy Commission, Division of Reactor Development, has been requested by the Maritime Reactors Branch to study the use of nuclear power for the propulsion of merchant ships. Representatives of various phases of the shipping industry were approached for their opinions regarding this new area of maritime development and trends in merchant ship design and operating characteristics.

The result is an industry-wide summary of the latest opinions, impressions, and practices for ship building and operation. Wide variations in expressed opinions are apparent in this report since the persons contacted represented several different phases of the maritime industry. A large amount of valuable information was gathered concerning types of ships which may be most feasible for nuclear propulsion from the standpoint of operating economics and technological advancement. In addition, problem areas requiring resolution before private industry is willing to proceed with active participation in the field of nuclear ship propulsion are identified.

It should be noted that the statements, questions, and conclusions indicated in this survey report are those of private industry personnel and are not intended to reflect the opinions of the Atomic Energy Commission, its staff, or any of its contractors.

AWS-TR-105-142

Kochanski Adam B
WIND, TEMPERATURE AND THEIR VARIABILITIES TO 120,000 FEET, Headquarters, Air Weather Service, Military Air Transport Service, USAF, Washington 25, D.C., May (1956), 34 pp. (12 refs).

1. Purpose - To acquaint AWS forecasters and climatologists with the variability (or persistence) of winds and temperatures up to 120,000 feet. This is the ninth report of a series which presents background material to AWS Manual 105-50, "Forecasting Upper-Level Winds," (in several parts). The previous background reports are AWS Technical Reports 105-86, 105-96, 105-107, 105-108, 105-115, 105-121, 105-128, and 105-129.

2. Scope - Time-height cross sections of daily winds, and graphs of wind variability with height are presented for four stations situated close to the 70°W Meridian and ranging from 28°N to 61°N. The variabilities are discussed in light of their application as persistence "forecasts" of upper-level winds. The data analyzed are for the months of August 1954 and January 1955. Graphs of temperature and daily temperature changes are also given. In addition, Chanute AF Base data are included for January 1955 only.

3. Credits - The Evans Signal Laboratory, Fort Monmouth, N.J., provided special equipment for the balloon flights from which the basic data were derived. In addition, the wind computations were accomplished by Signal Corps personnel in the Laboratory.

4. Additional Copies - This Technical Report is stocked at Headquarters MATS, Command Adjutant, Publishing Division. Additional copies may be requisitioned from Headquarters, Air Weather Service, Attn: AWSAD, in accordance with AWS Regulation 5-3, as amended.

BMI-1292

Stang John H, Coldthwaite William H and Dunnington Bruce W
DESIGN FEATURES OF CAPSULES FOR HIGH-TEMPERATURE IRRADIATIONS,
Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio,
Contract No. W-7405-Eng-92, September 22, 1958, 16 pp. (3 refs).

An analysis was made of the problems of control and measurement of specimen temperature and heat generation in a NaK-filled capsule containing a fuel specimen. A specific problem is used in this report to demonstrate the large uncertainties normally encountered even in capsules containing thermocouples. This analysis indicates that an improvement by a factor of more than three (i.e., from an uncertainity of $\pm 70^{\circ}$ to $\pm 20^{\circ}$F in the example used) may be obtained by use of a differential-thermocouple heat-flow meter and by use of a precision thermocouple-placement clip.

Since the irradiation damage suffered by fuel specimens is sensitive to small changes in temperature and burnup, improvements in precision in irradiation testing are of great importance in fuel studies. If the indicated improvement of precision by a factor of three is actually obtained when capsules of this design are irradiated, the experimenter will be able to draw much more reliable conclusions from a given testing program.

BNL-203

Dwyer O E, et al.
HEAT TRANSFER RATES FOR CROSS FLOW OF WATER THROUGH A TUBE TANK AT HIGH REYNOLDS NUMBERS,
Brookhaven National Laboratory, Upton, N.Y., Contract No. AT-(32-3)-Gen-16, November 20, 1952, 78 pp.

Film heat transfer coefficients have been obtained for cross flow of water through a tube bank under the following conditions:

tube size, 0.810-in. OD
tube length, 12 in.
tube spacing, 1-9/32-in. equilateral pitch
lattice size, 10 tubes wide x 20 tubes long
bulk water temperature, 360°F
maximum number of active elements, 3
maximum temperature rise of water, 0.4°F/pass

Average heat transfer coefficients, on an individual tube basis, have been determined for various positions in the lattice.

CF-55-2-4

Arnold E D and Gresky A T
FEASIBILITY STUDY: USE OF ODOROUS WARNING AGENTS IN RADIO-CLOUDS,
Oak Ridge National Laboratory, Oak Ridge, Tenn., February 1, 1955, 8 pp.

This report presents the results of a brief investigation of an odor warning system to trace radio-clouds, e.g., from HRT incidents, and indicates that such a public protection technique is feasible and worthy of some further consideration. The ultimate choice of the optimum odorous agent and methods for release or dispersal were not considered.

FZM-1702

Dvorak H R
OUTLINE OF CONVAIR RADIATION EFFECTS RESEARCH PROGRAM FOR NUCLEAR POWERED AIRCRAFT,
Convair, Fort Worth, Texas, May 14, 1958, 32 pp.

This document contains the charts used to explain Convair's goals and examples of achievements in radiation effects.

GE-GEL-BA-75

Ryan J W and Langdon W R
BIBLIOABSTRACT ON RADIATION EFFECTS,
General Electric Co., Schenectady, N.Y., August 2, 1954, 134 pp.

This is a bibliography listing some 528 references pertaining to radiation effects. Brief abstracts are included for each. The references are related to the following general topics: biological effects, chemical effects, electrical effects, mechanical properties, metallurgical effects, optical properties, and thermal effects.

HW-14764 (Del)

Carbon M W
SPECIAL IRRADIATION OF TEMPERATURE-INDICATING LIQUID,
Pile Technology Section, Technical Divisions, Hanford Works, Richland, Washington, Contract No. W-31-109-Eng-52, August 18, 1949, 1 p.

A sample of "Tempilaq" (a commercially available temperature-indicating liquid) was irradiated in the E-test hole of the F-pile for 21 days. It was then placed in an electric furnace and was found to melt at its designated melting point within the error of the furnace temperature-indicating apparatus. One such test does not provide conclusive data, but it does indicate that the melting point properties of the substance are unaffected by moderate exposure to radiation.

HW-40142

Woodley R E
THE PROMOTION OF CHEMICAL REACTION BY PILE RADIATION - FINAL REPORT PRODUCTION TEST 105-504-E,
Pile Technology Section, Engineering Department, Hanford Atomic Products Operation, Richland, Washington, Contract No. W-31-109-Eng-52, November 22, 1955, 52 pp. (33 refs).

The effect of pile radiation on the chemical systems, graphite plus carbon dioxide, graphite plus 85% CO_2 - 15% N_2, graphite plus 70% CO_2 - 30% He, graphite plus oxygen, graphite plus liquid water, graphite plus water vapor carried by nitrogen, carbon dioxide in the absence of graphite, carbon monoxide in the absence of graphite, and carbon tetrafluroide plus aluminum, has been investigated by exposing these systems to the intense radiation in an in-pile water-cooled facility. The results demonstrate that:

1. The low temperature irradiation of graphite under an atmosphere of carbon dioxide results in the formation of carbon monoxide, part of which subsequently decomposes

to form carbon dioxide and a solid polymer of one or more carbon suboxides. A very slow approach to equilibrium is indicated by the constancy of ion pair yields and G values.

2. The dilution of carbon dioxide with either nitrogen or helium results in a decreased rate of carbon dioxide reduction as a consequence of its decreased partial pressure. Both diluents increase the dosage received by the carbon dioxide however. Ion pair yields and G values show satisfactory agreement with those calculated for the graphite-pure carbon dioxide system.

3. In the absence of graphite, the radiation induced reduction of carbon dioxide rapidly attains an equilibrium state with about one per cent of the carbon dioxide reduced to carbon monoxide and oxygen.

4. Upon irradiation, graphite reacts with oxygen to form carbon dioxide at a rate which appears to be about three times as rapid as the reduction of carbon dioxide by graphite.

5. The formation of hydrogen and carbon dioxide occurs when graphite is irradiated in the presence of liquid water. The decomposition of water into hydrogen and oxygen proceeds rapidly to a steady state. Carbon dioxide is subsequently formed in the reaction of graphite with oxygen.

6. The extent of reaction between graphite and water vapor carried by nitrogen was limited by the amount of water vapor present. The reaction results in the formation of carbon dioxide and hydrogen.

7. Carbon monoxide decomposes to carbon dioxide and a solid polymer of one or more of the carbon suboxides upon exposure to pile radiation. The carbon content of the polymer increases with increasing dosage.

8. Carbon tetrafluroide reacts only slightly with aluminum upon irradiation but undergoes an extensive reaction with the quartz ampoule. The latter reaction was essentially complete and resulted in the formation of carbon dioxide and silicon tetrafluoride.

IDO-16434 (Part IV)

Birkhoff G, et al.
SPHERICAL BUBBLE GROWTH,
The Ramo-Wooldridge Corp., Los Angeles, Calif., November 25, 1957, 14 pp.

Plesset and Zwick have calculated the rate of growth of vapor bubbles in slightly superheated steam under constant external pressure. Their calculation assumes that the temperature drop is localized in a thin "boundary layer" near the bubble wall; the predicted bubble radius R(t) is asymptotically proportional to $t^{1/2}$ when R is large enough for surface tension to be negligible.

An analysis of this asymptotic phase is given below, which avoids the above "boundary layer" assumption, and contains that part of the analysis of Plesset and Zwick dealing with this phase as a limiting case. The analysis is shown to be (approximately) applicable also also to gas bubbles in supersaturated liquids.

LAC-NR-51 (Vol.1)-1

Collins C G
APPLICATION OF RADIATION EFFECTS DATA TO NUCLEAR AIRCRAFT PROBLEMS,
Aircraft Nuclear Propulsion Department, General Electric Co., Cincinnati, Ohio. Paper presented at the 3rd Semiannual Radiation Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corporation, Marietta, Ga., 18 pp. (19 refs).

The addition of a nuclear environment to the environments normally encountered by the aircraft designer has required that the suitability of materials and components be reassessed on a broad scale. Much of the activity of materials engineers and designers of the past few years has been concerned with this assessment. This report presents a summary of the concepts and procedures utilized in applying radiation effects data to the solution of design problems and comments on developments of the past year.

Conceptually, application of radiation effects data involves, simply, the comparison of observed effects on materials properties with the properties requirements of the anticipated application. The analytical processes necessary in implementing this comparison include consideration of the various radiation dosage units, determination of the relative effectiveness of different types of particles in producing damage, and the evaluation and extrapolation of data. Limiting factors in such an analysis include difficulties with dosimetry, lack of knowledge of radiation effects under combined environments, and limited knowledge of the materials properties necessary in specific engineering applications.

Despite the approximations necessary, this analytical approach serves a number of purposes to real advantage. Preliminary materials selection can be made with sufficient confidence that the major effort of design and development can proceed; time is thereby gained in which to define materials performance. Key problem areas have been defined, and the definition has led to studies to develop new and improved materials.

LAC-NR-51 (Vol. 3)-26

Osterman John A
PNEUMATICS - A TOOL FOR THE DESIGNER OF NUCLEAR POWERED AIRCRAFT,
Lockheed Aircraft Corporation, Marietta, Ga. Paper presented at the 3rd Semiannual Effects Symposium, October 28-30, 1958, Lockheed Aircraft Corp., Marietta, Ga., 6 pp.

Pneumatics has been demonstrated to have promise in the field of high temperature aircraft system operation. Air has greater resistance to nuclear radiation and is capable of operating over a wider range and higher temperatures than any available hydraulic fluid. This paper gives the essential results of a program of study of a high temperature pneumatic system which offers a promising tool to the nuclear aircraft system designer.

NESC-57-17

Carlton P F
THE APPLICATION OF RADIOISOTOPES TO THE MEASUREMENT OF SOIL MOISTURE CONTENT AND DENSITY,
Corps of Engineers, US Army, 5851 Mariemont Avenue, Cincinnati, Ohio. Published by The American Society of Mechanical Engineers, for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 11 pp. (14 refs).

The physical basis of the method, as well as the design and operational characteristics of portable instruments now being used for field measurements of soil moisture content and density are described. Application of the method to engineering studies is discussed, as is the development now in progress for improving the current design of the instruments.

NARF-57-19T (Vol. 4)-1

Batchelder H R and Lyons C J
RADIATION EFFECTS INFORMATION CENTER,
Battelle Memorial Institute, Columbus, Ohio. Paper presented at the First Semiannual 125A Radiation Effects Symposium, May 22-23, 1957, Convair, Ft. Worth, Tex., 12 pp.

The Radiation Effects Information Center has been established at Battelle Memorial Institute by the Air Force to provide a rapid means of placing radiation effects data in the hands of weapons system designers and those conducting research and development. The radiation effects of primary concern are those of gamma and neutron on materials and systems outside a reactor and not in the crew compartment. A combined team of technologists familiar with materials and operating systems likely to be used in airborne weapons systems, and information specialists will collect, extract, and file for use radiation effects data. These data will be available for direct use at Battelle and in the field and also will be summarized in the form of state-of-the-art reports on broad classes of materials and systems, and technical memoranda on specific items. In addition, special reports will be issued compiling information where a need exists or to answer requests of the Air Force. The Center has been established to support the 125A program, but the Air Force plans to extend its use and services to the Army, Navy, and other government agencies and the supporting contractors of each.

NESC-57-64

Martini W R and Churchill S W
NATURAL CONVECTION INSIDE A HORIZONTAL CYLINDER,
The University of Michigan, Ann Arbon, Michigan. Published by The American Society of Mechanical Engineers, for the 2nd Nuclear Engineering and Science Conference, Philadelphia, Pa., March 11-14, 1957, 14 pp. (10 refs).

The two vertical halves of the wall of a horizontal cylinder were maintained at different uniform temperatures. The rate of circulation of air inside the cylinder and the local and overall rates of heat transfer to the wall were computed from measurements of the temperature and velocity fields in the air.

The conclusions found were:

1. The air circulates rapidly in a narrow band near the wall while the central core of air is essentially stagnant.
2. The circulation rate appears to go through a maximum and then decrease with increasing wall temperature difference.
3. The local heat transfer coefficient varies considerably with angle and increases only slightly with increasing wall temperature difference.

4. The overall rate of heat transfer by convection for air at atmospheric pressure inside a 4.3" cylinder corresponds to a coefficient of approximately 0.3 BTU/hr sq ft (^{O}F) or a Nusselt number of approximately 7 over a range of wall temperature difference from 3.5 to 367^{O}F.

NP-5906

RADIOCHEMICAL LABORATORY MANUAL,
Advance Technology Corporation, Subsidiary of Nuclear Development Associates, Inc., White Plains, N.Y., Contract No. DA18-108-CML-4522, November 15, 1953, 379 pp.

This manual was prepared for the radiochemical (RW) section of the Chemical Corps. This is the basic laboratory manual for the RW section. It reviews principles of physics and chemistry, special laboratory techniques, specific "cook book" type analytical procedures, and data as are considered important to RW sections operation.

The fact that there is little if any actual combat experience in atomic and radiological warfare poses a real problem. The field laboratory man will be faced with executing assignments without essential military intelligence. He will be thus largely dependent on his resourcefulness in improvising, experimenting and analyzing for each new situation.

NRC-1835

Rose B
GAMMA RAYS FROM THE DISINTEGRATION OF BORON BY SLOW NEUTRONS,
Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio, November (1948), 12 pp. (23 refs).

The slow neutron disintegration of B^{10} yields two groups of α-particles, corresponding to the production of Li^{7} in either the ground state or an excited state. The γ-radiation accompanying the de-excitation of the excited nucleus was studied. Boron in the form of boron trifluoride in a proportional counter was irradiated with slow neutrons from a Ra-α-Be source. Coincidences were counted between α-particle pulses in the proportional counter and γ-ray pulses in an adjacent Geiger-Müller counter. The ratio of the α-γ coincidence rate to the α-rate gave the product of the efficiency of the Geiger-Müller counter and the number of quanta emitted per boron disintegration. The absorption coefficient of the γ-radiation in lead was measured, and by comparison with the absorption coefficients for the γ-radiation from Cu^{61} and Au^{195}, the energy was found to be 0.48 ± 0.015 Mev. The quantum efficiency of the Geiger-Müller counter for radiation of this energy was determined by calibration with standard sources of Co^{60} and thorium active deposit. Hence the number of quanta per boron disintegration was found to be 0.90 ± 0.08, in satisfactory agreement with the value to be expected from the relative abundance of the α-particle groups from this reaction.

NRL-Q-1(1)

Schulman James H, et al.
SOME OPTICAL PROPERTIES OF LEAD-ACTIVATED SODIUM CHLORIDE PHOSPHORS,
Journal of the Optical Society of America, Vol.40, No. 12, pp. 854-862, December (1950), (11 refs).

Absorption and luminescence phenomena in NaCl:Pb phosphors have been found to be rather complex. Melt-grown, NaCl:Pb has an asymmetrical, 2730A-peaked absorption band. The variation of emission spectrum with wave-length of excitation within this band shows that it consists of two poorly resolved absorption bands, one peaking at 2730A and the other at 2900A. At low Pb concentrations, irradiation into the first of these causes a near-ultraviolet emission peaking at 3200A; irradiation into the second causes a visible emission peaking at about 4500A. At high Pb concentrations, irradiation into the first band gives a second near-ultraviolet emission band peaking at 3850A in addition to the one peaking at 3200A. Precipitated NaCl:Pb shows all the above phenomena, and in addition, has an excitation band peaking at 2600A, producing simultaneously a 3300A-peaked emission and a visible emission. The NaCl:Pb phosphors are unstable, deteriorating after a few days at room temperature and more rapidly at 130^{o} X-irradiation of these phosphors destroys the above absorption and emissions, and gives a print-out effect due apparently to the formation of colloidal Pb. The X-rayed material can be excited by near ultraviolet to give a red emission, peaking at about 6100A. Some suggestions concerning the interpretation of the above phenomena are given.

NRL-Q-1(3)

Schulman James H, et al.
ENCHANCEMENT OF X-RAY INDUCED ABSORPTION BANDS IN ALKALINE EARTH COMPOUNDS,
Journal of Chemical Physics, Vol.20, No. 12, pp. 1966-1967, December (1952), (5 refs).

It is deduced that the incorporation of monovalent positive ion impurities in alkaline earth salts should increase the discoloration of these compounds by ionizing radiations. This deduction is confirmed experimentally with alkaline earth fluorides and strontium sulfate "sensitized" with alkali-ion impurities. As predicted, M^{+3} ions and X-ray-ion impurities poison the sensitizing effect of the M^{+1}-ion impurities.

NRL-Q-1(5)

Etzel H W and Schulman J H
SILVER-ACTIVATED ALKALI HALIDES,
Journal of Chemical Physics, Vol.22, No. 9, pp. 1549-1554, September (1954), (17 refs).

The emission, excitation, and absorption spectra of silver-activated alkali halides have been investigated. Three absorption bands due to ionic silver have been observed in NaCl, NaBr, KCl, and KBr, and the growth of these bands with silver concentration has been studied. In each of these crystals the two shorter wavelength bands are ascribed to isolated silver ions, while the band of longest wavelength is ascribed to pairs of silver ions.

Upon X-ray irradiation as many as five new absorption bands arise in certain alkali halides in addition to the F-band. Excitation into three of these bands (designated as the B, C, and D bands) produced luminescence, the emission spectrum being different for each band. The B-band is attributed to a center consisting of an electron trapped at a silver ion adjacent to a halogen-ion vacancy; the C-band to an electron trapped at a complex of two silver ions adjacent to a halogen-ion vacancy; and the D-band to a hole trapped at an alkali-ion vacancy adjacent to a silver ion.

NRL-Q-1(9)

Compton W Dale
PRODUCTION OF COLLOIDAL SODIUM IN NaCl BY IONIZING RADIATION,
The Physical Review, Vol. 107, No. 5, pp. 1271-1275, September 1, 1957, (10 refs).

A study has been made of the coloration of synthetic and natural sodium chloride crystals with Co^{60} gamma-ray and 1.3-Mev electron irradiations. These irradiations produced the colloid band, at 565 mμ, in the synthetic crystals but not in untreated natural crystals. Various thermal treatments were given natural crystals prior to their coloration. It was found that either type of irradiation would produce colloids in crystals that had been heated at 700°C for at least 24 hours in an atmosphere containing hydroxyl ions. Colloids were produced in the untreated natural crystals by additive coloration. It was found that the characteristics of the colloids were the same whether they were produced by ionizing radiation or by additive coloration, with the exception of the role played by hydroxyl ions in the crystals colored by ionizing radiation.

NYO-3307

Bretton R H
EFFECT OF GAMMA RADIATION ON CHEMICAL REACTIONS. - I. INSTALLATION OF COBALT-60 RADIATION SOURCE,
Progress Report No. 1 (Fourth Quarter, 1951), Yale University, New Haven, Conn., Contract No. AT-(30-1)-1173, January 20, 1952, 12 pp.

A kilocurie $Cobalt^{60}$ gamma radiation source has been received from Brookhaven National Laboratory and installed in a designated region of a single-story laboratory annex building.

The pig containing the source is supported on a base 17 " high and enclosed by a concrete wall 8" thick and 5' high. A pulley system for use in the removal of the plug has been constructed.

A survey of the radiation field around the pig has been made. Even though a certain amount of downward scattering and reflection of the high intensity beam apparently occurs when the beam impacts on the ceiling, no region of excessive intensity was found outside of the confined region designated for the pig installation.

NYO-3309

Bretton R H (Project Director)
EFFECT OF GAMMA RADIATION ON CHEMICAL REACTIONS. - II. PRELIMINARY INVESTIGATION OF VAPOR-PHASE POLYMERIZATION OF ACETYLENE AND ETHYLENE,
Progress Report No. 2, Yale University, New Haven, Conn., Contract No. AT-(30-1)-1173, April 25, 1952, 11 pp. (4 refs).

A hollow-bore access plug has been fabricated which permits a reaction vessel to be connected to a pressure measuring device when the former is in position in the $Cobalt^{60}$ vault. Glass reaction vessels for use with this plug have been obtained.

A radiation warning system which is controlled by the ammeter circuit of a Beckman MX-3A radiation meter has been constructed. In normal use, this system is adjusted to actuate when the access plug is removed from the pig, causing a red lamp to light and a buzzer to operate.

NYO-3310

EFFECTS OF GAMMA RADIATION ON CHEMICAL REACTIONS. - III. PRELIMINARY INVESTIGATION OF VAPOR-PHASE POLYMERIZATION OF ETHYLENE AT ROOM TEMPERATURE AND ATMOSPHERIC PRESSURE,
Progress Report No. 3, 2nd Quarter, 1952, Yale University, New Haven, Conn., Contract No. AT-(30-1)-1173, July 25, 1952, 14 pp. (5 refs).

A preliminary investigation of the gamma initiated polymerization of ethylene at atmospheric pressure and room temperature has been made. In several runs, the rate of decrease of the total pressure of the gas samples being irradiated was measured, the residual gas was analyzed for hydrogen and saturated hydrocarbons, and the characteristics of the resulting polymer were observed.

The observed rates of pressure decrease can be represented by first order rate constants of the order of magnitude of 0.01 per day.

In contrast to the results of Lind on the alpha-particle initiated reaction of ethylene and the electrical discharge reaction of ethylene, substantial amounts of hydrogen or saturated hydrocarbons were not found in the residual gas in the present investigation. It is difficult to accurately describe the polymer obtained, except to say that it is a yellow, or sometimes red, colored solid which is in evidence only near the bottom portion of the reactor at the end of a run.

The following tentative conclusions have been formulated:

1. The over-all rate of reaction apparently decreases as the surface-volume ratio is increased.
2. The amounts of hydrogen and saturated hydrocarbons formed, though small, appear to increase with the total radiation dosage.
3. The polymer apparently undergoes changes after it is deposited, presumably as a result of further absorption of gamma radiation.
4. Traces of air, if present with the ethylene, do not affect the rate of ethylene reaction.
5. The ion-pair yield is apparently of the order of magnitude of 30, which indicates that the reaction proceeds by a chain-type mechanism.

NYO-3312

EFFECT OF GAMMA RADIATION ON HYDROCARBON GASES,
Progress Report No. 5, Yale University, New Haven, Conn., Contract No. AT-(30-1)-1173, June 30, 1953, 12 pp. (4 refs).

The effect of temperature on the radiation initiated polymerization of pure acetylene in the range of 80°F and 450°F was investigated in a pyrex glass reaction vessel, having a surface volume ratio of about 1.80 cm^{-1}. The rate data obtained were derived from total pressure measurements made on a batch system of acetylene. The polymerization rate was found to be independent of temperature in the range of 80° - 250°F. Above 250°F there was an increase in the polymerization rate accompanying an increase in temperature. Assuming that the polymerization rate is the additive result of two

mechanisms, one of which is predominant below 250°F, the temperature dependent mechanism, that is observable only at temperatures above 250°F, is found to correspond to an activation energy of 11.3 k-cal/gm mole.

The effect of thermal polymerization of acetylene in the absence of a radiation field was investigated in the range of 440° and 650°F. An activation energy of 50 k-cal/gm mole was obtained. Pure thermal polymerization is insignificant below 450°F.

Preliminary investigation of the effect of pressure and inert gases, and the reproducibility of results of the radiation initiated polymerization of acetylene has been carried out. The following tentative conclusions can be made:

1. Reproducibility of results of runs conducted in a single reactor has been established. When different reactors were used having the same surface-volume ratio, results were not reproduced.
2. Acetone acts as a sensitizer in the radiation initiated polymerization of acetylene, to give a first order rate constant greater then that obtained by pure acetylene.
3. At pressures between 650 and 1400 mm Hg, the polymerization rate of acetylene is independent of pressure. Below 650 mm Hg, the rate decreases with a decrease in pressure.
4. At approximately the same total pressure, the polymerization rate decreases as the percentage of air or nitrogen is increased.

NYO-3311

EFFECT OF GAMMA RADIATION ON HYDROCARBON GASES,
Progress Report No. 4 (3rd Quarter, 1952), Yale University, New Haven, Conn., Contract No. AT-(30-1)-1173, October 30, 1952, 14 pp. (3 refs).

The nature of the effect of temperature on the gamma-initiated polymerization of ethylene, below temperatures at which a significant amount of thermal polymerization would occur, has been investigated. Polymerization rate data have been obtained at nearly atmospheric pressure in a pyrex glass reaction vessel, having a surface-volume ratio of about 1.8 cm^{-1}, at six temperatures between 880°F and 372°F. The rate data were derived from total pressure measurements made on a batch system of ethylene. It was assumed, on the basis of the results of certain preliminary runs, that the extent of formation of gaseous products was negligible.

The polymerization rate was found to be essentially independent of temperature in the range of 80° to 175°F. Above 175°F, the increase in polymerization rate accompanying an increase in temperature corresponded to an apparent activation energy of the order of magnitude of 7 k-cal/g-mol.

Preliminary investigation of the effect of pressure, nature and extent of surface, source of acetylene on the gamma-initiated polymerization of acetylene has been carried out.

The following tentative conclusions can be made:

1. The order of magnitude of the ion pair yield (M/N = 20) indicates a chain-type mechanism.
2. The rate of reaction decreases as the surface volume ratio is increased.

3. The nature of the surface plays a very important role in the apparent rate of reaction.

4. The reaction probably proceeds by two mechanisms, one of which is negligible at the higher pressures.

5. Acetone, when present in small amounts, may act as a sensitizer in the formation of the aromatic product by terminating the chain.

NYO-3320 CU-3-54-AEC-1186-Chem

FOOD IRRADIATION AND ASSOCIATED STUDIES,
Termination Report - Part I, Columbia University, New York, N.Y., Contract No. AT-(30-1)-1186, September 15, 1954, 47 pp. (41 refs).

This report covers an animal feeding experiment in which rats were fed gamma-irradiated butterfat. Other subjects covered includes effect of irradiated diet on rats, oxidative deterioration in irradiated milk, effect of gamma radiation on fats and the gamma-ray induced oxidation of ascorbic acid and ferrous ion.

NYO-4611

Dennis Richard, et al.
AIR CLEANING STUDIES,
Progress Report for July 1, 1954 to June 30, 1955, Harvard University, Boston, Mass., Contract No. AT-(30-1)-841, October 15, 1956, 50 pp. (14 refs).

This report covers progress on the air and gas cleaning project conducted by Harvard University for the Engineering Division of the Atomic Energy Commission during the period July 1, 1954 to June 30, 1955. Primary objectives of this project include: (a) research and development on air and gas cleaning devices and methods for their testing and evaluation, (b) training and education of commission and contractor personnel, (c) collection and correlation of information on air and gas cleaning techniques, and (d) consultation services. Investigations on the role of electrostatic forces in gas cleaning, studies on resistance and filtration characteristics of fiber media, a study of dust re-entrainment from filters exposed to shock waves, and rating of high efficiency roughing filters were continued during this period. New projects included determination of gas cleaning requirements for a pilot model institutional incinerator, a theoretical study of the behavior of null-type sampling probes, evaluation of miniature cyclones for gas sampling, and laboratory testing of a new type wet scrubber and two commercial collectors employing electrified fiber mats.

NYO-8527

Friedman Helen C
DEVELOPMENT OF CERMETS,
A Bibliography; Penn-Texas Corporation, New York 19, N.Y., Contract No. AT-(30-1)-1991, June 7, 1957, 31 pp. (384 papers).

This bibliography surveys recent developments of metal-nonmetal combinations including mixtures of metallic and nonmetallic powder particles which are especially suitable for the slip casting process. The pressureless forming, which is the aim of slip casting, will avoid stresses in the compact which usually result with the conventional compacting under pressure.

This bibliography should be valuable to any research worker involved in cermet development, not only for nuclear reactor applications, but also for high temperature purposes.

ORNL-2389

Blizard E P (Director)
APPLIED NUCLEAR PHYSICS DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING SEPTEMBER 1, 1957,
Oak Ridge National Laboratory, Oak Ridge, Tenn., Contract No. W-7405-Eng-26, November 26, 1957.

Each paper listed in this document is abstracted and referenced independently.

ORNL-2389-9

Fox J K and Gilley L W
CRITICAL PARAMETERS OF AQUEOUS SOLUTIONS OF U^{235},
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 13 pp. (4 refs).

The series of experiments to determine the critical parameters of aqueous solutions of UO_2F_2 highly enriched in U^{235} is continuing. Additional experiments have been performed to determine the critical parameters of unreflected and water-reflected solutions in single vessels of varying size. The effect of special reflectors on single vessels also has been determined. In addition, arrays of interacting vessels have been studied. The U^{235} enrichment of the solution used in these experiments was 93.2%.

ORNL-2389-24

LaVerne M E
PROGRAM COMPILER FOR THE ORACLE,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 1 p. (3 refs).

The compiler, which was previously reported, has been revised for use with the Oracle's new input-output equipment. A compilable version of the compiler is being prepared.

ORNL-2389-26

Sullivan J G, et al.
ORACLE SUBROUTINES,
Applied Nuclear Physics Progress Report for Period Ending September 1, 1957, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 26, 1957, 2 pp.

Sentence descriptions are given of thirty-one subroutines which have been prepared for specific problems to be computed on the Oracle but are of general use to Oracle programmers.

PB-121302

Schultz H W, Dr.
FLAVOR OF FOODS STERILIZED BY COMBINING CONVENTIONAL PROCESSING WITH IONIZING RADIATION,
US Department of Commerce, Office of Technical Services, Prepared by Food Technology Department, Oregon State College, Corvallis, Oregon, Contract No. DA44-109-qm-1782, October (1955), 51 pp.

This report covers a series of tests on the flavors of meats that were irradiated for preservation. Main considerations were given to taste analysis by a panel of tasters using a ballot for the tastes to show differences in taste from a reference sample.

R-853

TEMPERATURE ANALYZER FOR TURBOJET AND TURBOPROP ENGINES,
Avien, Inc., Woodside, N.Y., March 25, 1958, 22 pp.

(Proprietary information)

RDB(W)/TM-1226

Bates J C
A NOTE ON THE COLLECTION AND ANALYSIS OF THE GAS CONTAINED IN IRRADIATED CARTRIDGES,
United Kingdom Atomic Energy Authority, Sellafield, Camb., England, April 18, 1958, 7 pp.

Gas released during the decanning of cartridges in analysis of the samples collected are given. The large volumes of hydrogen found led to the development of a method of sampling the gas directly from the cartridge cans, which has shown that the hydrogen was not present as gas in the cartridge after irradiation but resulted from the decanning. Analyses of the latter samples are also given.

REM-835

Dahlberg O K
RADIATION EFFECTS MANUAL - TEXTILES,
Convair, A Division of General Dynamics Corp., Fort Worth, Texas, October (1958), 65 pp. (5 refs).

Radiation damage analysis has shown that dacron is superior to all the other fabrics used in aircraft production. Figure 16 compares the major fabrics at a 25% damage dose. Also indicated are certain improvements that can be obtained in breaking strength through coatings, dyes, etc. This is generally true for all textiles but in some cases the improvement is marginal or renders the material unsuitable for a specific application. This limits the usefulness of the various conditioning processes that give improved radiation resistance. It has also been noted that water proofing cellulose and protein fibers will give improved radiation resistance.

Aircraft fabrics discussed are dacron, orlon, wool, dynel, rayon, cotton, and nylon.

SAE-58-92C

Miller M M and Liebshultz A M
THE RADIATION EFFECTS TESTING OF AIRCRAFT SYSTEMS,
Lockheed Aircraft Corp., Marietta, Ga., October (1958), 6 pp. (4 refs).

The evaluation of aircraft systems performance characteristics in a radiation environment are discussed. Environmental factors and requirements for conducting irradiations on dynamic systems are emphasized. Some major requirements for test facility capabilities are presented and a facility meeting these requirements is described. The facility functions are detailed by following a test item through the sequence of operations for a typical test program.

SC-4142(m)

PHOTOGRAPHIC INSTRUMENTATION HANDBOOK,
Sandia Corporation, Albuquerque, New Mexico, (1957), 40 pp.

This edition of the Photographic Instrumentation Handbook has been compiled to explain some of the important photographic-optical systems used at Sandia's ballistic test ranges.

Uses of the following basic instrumentation systems available at two of our test ranges are discussed: Cinetheodolites, Tracking Telescopes, Night Cameras, and Ballistic Cameras.

Pictures, data, and maps are arranged to give the engineer a convenient reference.

SCS-7 (July 1956)

ENVIRONMENTAL REQUIREMENTS AND TESTS FOR UNIVERSAL COMPONENTS,
Sandia Corporation, Albuquerque, New Mexico, July (1956), 15 pp.

This document presents the environmental requirements and tests for universal components. This standard defines environmental conditions and tests for those components which have a wide latitude of applications.

SCTM-93-57(14)

Bussey G R
SYMBOL AND ENTITY ASSOCIATION LOCATOR AND CORRELATOR,
Sandia Corporation, Albuquerque, New Mexico, Contract No. AT-(29-1)-789, April 24, 1957, 9 pp.

Two methods are described for rapid location and correlation of information from such sources as library collections, personnel records, and electrical equipment histories.

SCTM-94-57(14)

Bussey G R
A CONSTRUCTIVE PLAN FOR LIBRARY AUTOMATION,
Sandia Corporation, Albuquerque, New Mexico, Contract No. AT-(29-1)-789, May 15, 1957, 9 pp.

A plan is proposed for automation of library cataloging and literature searching by means of word symbolization and statistical principles.

SCTM-97-57(14)

Bussey G R
A MULTIDIMENSIONAL ASSOCIATOR,
Sandia Corporation, Albuquerque, New Mexico, Contract No. AT-(29-1)-789, May 17, 1957, 16 pp.

The Multidimensional Associator is a logical machine which operates largely by direct association and minimizes use of the sequential operations which are characteristic of most computers. This memorandum describes the basic design of the machine and discusses potential applications in information retrieval and logic. Analogies are pointed out between operation of the machine and functioning of the human brain. (Presented at Albuquerque Meeting of the IRE Professional Group on Information Theory, December 1956.)

SCTM-198-55(16)

Milton Osborne
RADIATION INDUCED DEGRADATION,
Sandia Corporation, Albuquerque, New Mexico, August 26, 1955, 9 pp. (22 refs).

The literature has been pursued and tests on materials are in process at a reactor. In the meantime, an interim report concerning the present status of the investigation of the behavior of materials in the presence of radiation has been considered advisable. This memorandum, then, reviews the situation to date and recommends increased activity in the field of radiation induced degradation with special emphasis on materials evaluation.

SCTM-200-59(15)

Paulus W K
TECHNICAL INDEXING EXPERIMENTS WITH A CATALOG FILE,
Sandia Corporation, Albuquerque, New Mexico, June 9, 1959, 26 pp. (7 refs).

In anticipation of the completion of "peek-a-boo" punched card information retrieval device, the "MDA-2 Punch," studies were undertaken to discover how it might be efficiently applied to a collection of information. For a file of product catalogs, the necessary clerical processing is outlined. The history of the application is presented together with problems encountered and their solution. A brief theoretical discussion of the relations involved in information retrieval is presented. The retrieval components: punch, subject authority (SCTM-103-59(15)), and retrieving procedure are presented as an integrated system.

SCTM-263-58(51)

Longhurst J U and Hudson C C
RADIATION RESISTANCE IN NEUROTIC ANIMALS,
Sandia Corporation, Albuquerque, New Mexico, Contract No. AT-(29-1)-789, October (1958), 27 pp.

It has been demonstrated that an individual's radiosensitivity is not a matter of chance, but of the physicochemical make-up of the organism. We are concerned with finding a discriminant response that would classify animals as survivors and nonsurvivors before irradiation. Such a response should vary with and depend on the physiological condition of the animal, since this condition is related to radiosensitivity. Because it is readily observable and is also a delicate indicator of physiological condition, emotional responsiveness to stress was selected for investigation. This study is still in progress.

SO-3255

Hogan A J
DECOMPOSITION OF CARBON DIOXIDE BY IONIZING RADIATION,
Department of Chemistry, Rensselaer Polytechnic Institute, Troy, New York,
Contract No. AT-(30-3)-52, April 1, 1954, 27 pp. (7 refs).

The decomposition of carbon dioxide and a mixture of carbon dioxide and nitrogen dioxide by irradiation with the beta particles from Sr^{90}-Y^{90} at room temperature has been studied. The fact that irradiation of pure CO_2 produces only a very small amount of CO and O_2 due to the rapid reoxidation of CO to CO_2 is confirmed. When about 0.2% nitrogen dioxide is introduced, however, the rate of formation of CO and O_2 is about five times faster initially and is constant with time as long as the nitrogen dioxide concentration remains the same. About three molecules of CO per ion pair are formed. As the nitrogen dioxide is decomposed by the beta particles upon long irradiation, the yield of CO decreases.

Beta source and the apparatus used for the irradiation of the gases, measurement of the ion current, and analysis of the gases are also described.

TID-5315 (Vol 1)

VOLUME 1 - THE INTERNATIONAL CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY,
Geneva, Switzerland, August 8-20, 1955, 312 pp.

Report of the United States Delegation to the International Conference on the Peaceful Uses of Atomic Energy held by the United Nations; with appendices and selected documents.

TID-5315 (Vol. 2)

VOLUME 2 - THE INTERNATIONAL CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY,
Geneva, Switzerland, August 8-20, 1955, 555 pp.

Report of the United States Delegation to the International Conference on the Peaceful Uses of Atomic Energy held by the United Nations; with appendices and selected documents.

TID-7539-3

MacMillan D C
THE NUCLEAR POWERED PASSENGER-CARGO SHIP,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 18 pp.

It is the intent of this paper to discuss briefly the characteristics and significant naval architectural features of the nuclear powered passenger-cargo ship. It should be understood that the characteristics and design data presented are based on the preliminary design and are subject to further development during the contract design phase now underway.

(Nuclear Safety including containment, shielding, health physics, waste disposal, and refueling are covered.)

TID-7539-4

Grimes R P
DESIGN OF FIRST MERCHANT SHIP NUCLEAR PROPULSION PLANT,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 15 pp.

Atomic energy is a new source of heat which requires reactors, heat exchangers and other heavy primary loop equipment together with turbines and allied equipment for conversion of this energy to useful work.

The reactor, the cooling system, the core, the power generation equipment, and the propulsion system are discussed.

TID-7539-5

Gatewood Arthur R
ACTIVITY OF THE AMERICAN BUREAU OF SHIPPING RELATIVE TO NUCLEAR PROPULSION FOR MERCHANT SHIPS,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 5 pp.

This paper is an explanation of the place held by the American Bureau of Shipping in the field of nuclear powered merchant vessels, insofar as classification of ships is concerned.

TID-7539-6

Murphy C P, Capt.
COAST GUARD ACTIVITY RELATIVE TO NUCLEAR POWERED MERCHANT SHIPS,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 2 pp.

The Coast Guard's activities with respect to the nuclear powered merchant vessel stem from Federal statutes which require that merchant vessels comply with certain minimum safety standards. Such vessels must be inspected by the Coast Guard to ensure that they are seaworthy and can be navigated with safety to life. Based upon the statutes, a set of regulations has been developed over the years which set forth the standards for construction, machinery, equipment, and manning which will be accepted as complying with the requirements of the law.

TID-7539-7

Hope Malcolm C
PUBLIC HEALTH SERVICE INTERESTS IN THE PROBLEMS OF NUCLEAR PROPULSION OF MERCHANT VESSELS,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 2 pp.

This paper discusses the present duties of the Public Health Service in the merchant shipping field and possible extensions of duties when nuclear merchant ships become operable.

TID-7539-8

Cornwell Clifford G
MARINE INSURANCE FOR NUCLEAR POWERED COMMERCIAL VESSELS,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 6 pp.

This paper covers the problems of the insurance industry in indemnifying nuclear powered merchant shipping.

TID-7539-9

Stout Ernest G
OPERATION AND SUPPORT FOR NUCLEAR SHIPS,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 13 pp.

The purpose of this paper is to acquaint the various organizations actively interested in nuclear powered ship operations with the facilities and equipment required for operation. It must be conceded that data generated at this early stage must be general and preliminary in nature. It is realized that certain portions of the information are subject to revision and continued improvements as our technical knowledge and capabilities improve with program progress.

TID-7539-10

Parker F A, et al.
PROSPECTS FOR MARITIME NUCLEAR PROPULSION,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 21 pp.

This paper is concerned with the competitive economics of the nuclear powered merchant fleet versus conventional shipping.

TID-7539-15

General Motors Corporation-Research Staff
20,000-SHP NUCLEAR PROPULSION SYSTEM FOR TANKER; GENERAL SUMMARY AND CONCLUSIONS,
Paper presented at a Symposium--Nuclear Powered Ships for American Ship Operators--July 30, 1957. Sponsored by Maritime Reactors Branch, Division of Reactor Development, AEC, Washington, D.C., September (1957), 11 pp.

This paper is a summary of the characteristics of a 20,000 SHP Nuclear Propulsion System using a graphite moderated, enriched fueled, helium-cooled reactor.

TRJ-0258-1

Teszler Otto, Wiehart Hans and Rutherford Henry A
THE EFFECT OF NUCLEAR RADIATION ON FIBROUS MATERIALS - PART II. DYEING CHARACTERISTICS OF IRRADIATED COTTON AND RAYON,
Textile Research Journal, Vol. 28, No. 2, pp. 131-135, February (1958), (7 refs).

The dye adsorption characteristics of a series of cotton and rayon samples exposed for different periods of time to gamma rays and to thermal neutrons have been determined. For this work substantive dyes of known behavior toward degraded celluloses were used. The effect produced in the case of neutrons was twofold. At the early stages and again during the later stages of irradiation, the dye adsorption of the samples was increased; at intermediate exposures the adsorption was decreased. Because hydrolyzed cellulose behaves in the former manner and the acidic type of oxidized cellulose in the latter, the data suggest that neutrons have an effect similar to both hydrolysis and oxidation. Gamma rays (Co^{60}), however, gave only the effect of oxidation.

TRJ-0358-1

Blouin F A and Arthur J C, Jr.
THE EFFECTS OF GAMMA RADIATION ON COTTON - PART I. SOME OF THE PROPERTIES OF PURIFIED COTTON IRRADIATED IN OXYGEN AND NITROGEN ATMOSPHERES,
Textile Research Journal, Vol. 28, No. 3, pp. 198-204, March (1958), (5 refs).

Two series of samples of purified cotton were irradiated in oxygen and nitrogen atmospheres with gamma rays at six dosage levels ranging from 100,000 to 100,000,000 roentgens. Some of the chemical and physical properties of the irradiated cellulose were determined by means of various widely used techniques of cellulose chemistry. It was

found that high energy gamma irradiation of cotton resulted in carbonyl group formation, carboxyl group formation, and chain cleavage in the approximate ratio of 20:1:1; increased solubility in water and in dilute alkali; decrease in tensile strength of the fibers; small but unusual changes in moisture regain; relatively unchanged infrared absorption spectra; and the same type of degradation in a nitrogen atmosphere as in an oxygen atmosphere, with oxygen producing only slight enhancement of the reaction.

TRJ-0658-1

Teszler Otto, et al.
THE EFFECT OF NUCLEAR RADIATION ON FIBROUS MATERIALS - PART III. RELATIVE ORDER OF STABILITY OF CELLULOSIC FIBERS,
Textile Research Journal, Vol. 28, No. 6, pp. 456-462, June (1958), (12 refs).

Cotton, rayon, and acetate yarns were exposed for different periods of time to thermal neutrons and to gamma rays. The results have shown that total dose is the deciding factor in the extent of change in physical properties of the materials and that gamma rays (Co^{60}) alone have essentially the same effect as thermal neutrons when the energies from the two are equated. The decreasing order of stability of the materials was acetate, rayon, and cotton. The data suggest that there are linkages in the native cellulose molecule susceptible to radiation that are not present in the regenerated materials.

TRJ-1056-1

Teszler Otto and Rutherford H A
THE EFFECT OF NUCLEAR RADIATION ON FIBROUS MATERIALS - PART I. DACRON POLYESTER FIBER,
Textile Research Journal, Vol. 26, No. 10, pp. 796-801, October (1956), (12 refs).

Dacron polyester filaments of different draw ratios were prepared and were exposed to high-energy radiation from two sources. Exposure both in a reactor and to a cobalt-60 source resulted in an increase in the moduli of elasticity of the filaments. This indicated that crosslinking reactions took place and predominated over chain scission, particularly during the early stages of irradiation. Draw ratio, i.e., the degree of orientation of the filament, had an influence on the behavior. The materials of lower draw ratio tended to show more crosslinking than those of high draw ratio, the optimum being between 2.5:1 and 3.0:1. The degree of crosslinking in dacron under the conditions of these experiments was, however, of a low order of magnitude. The solubility of the filaments was decreased only slightly, and the melting point remained unchanged. The degree of crystallinity of the filament did not influence the behavior of the filaments.

Although the work has not yet been extended to many other polymers, it is believed that materials which show a marked tendency to cross link during exposure to high-energy radiation would show an effect similar to dacron. For example, polyethylenes of different degrees of orientation or of different pretreatments might well behave quite differently with respect to changes in properties brought about by a given level of radiation. This has been partially substantiated by some preliminary results obtained with polyethylenes of unknown history, but at the same time known to be different in character prior to irradiation.

UCRL-583

Taulis W J
THE DECOMPOSITION OF WATER,
University of California Radiation Laboratory, Berkeley, California,
Contract No. W-7405-Eng-48, February 10, 1950, 44 pp. (28 refs).

This report studies the mechanisms of decomposition of water by radiation. The decomposition of water by radiation falls, essentially, into two groups characterized by type and energy of radiation. The influence of O_2, H_2, and H_2O_2 on the decomposition of water are studied. The most distinctive feature for any of the free radical reactions, however, was the probability of capture while in the solvent cage. Once this factor is determined, the range and lifetime of the radicals can be calculated for any given set of conditions. Among the free radicals, the H-atom is predominantly active; mainly, because of its relatively simple structure and its ability to diffuse rapidly. The OH is next with the HO_2 being the least active of the three.

UR-418

Davis T P, Hinshaw J R and Pearse H E
A COMPARISON OF THE EFFECTS ON BARE PORCINE SKIN OF RADIANT ENERGY DELIVERED IN THE FORMS OF SQUARE AND SIMULATED FIELD PULSES,
University of Rochester, Rochester, N.Y., Contract No. W-7401-Eng-49, December 21, 1955, 14 pp. (11 refs).

The critical energy required to produce a 2+ burn in the Chester White pig has been used as a method of comparing the effectiveness of radiant energy delivered in the forms of "square pulses" and "simulated field pulses." With both types of pulse, increasing the time of exposure necessitates an increase in the total energy delivered in order to produce a 2+ burn. There is no significant difference between the scaling factors for the two types of pulse.

WADC-TN-55-118 AD-92498

Riley C F, Jr. and Walker P F
ATMOSPHERIC CONTAMINANT, RADIATION, AND ELECTRICITY CRITERIA FOR AIRCRAFT AND AIRBORNE EQUIPMENT,
Booz, Allen and Hamilton, Contract No. AF33(616)-2689, June (1955), 122 pp. (references).

The characteristics, distribution of occurrence, effects on aircraft and equipment and preventive measures for various less troublesome environmental factors are presented in this report. The factors covered are static electricity, lightning, sand and dust, solar radiation, ozone, cosmic radiation, noise, insects, explosive atmospheres and nitric acid fumes.

Static electricity and sand and dust are found to be the most damaging of those environments discussed. The importance of static electricity is due primarily to its interference with electronic communication, navigation and control equipment, while sand and dust, particularly in the dry areas of the world, is capable of entering and damaging a wide variety of aircraft and equipment mechanisms. Solar radiation, ozone and cosmic radiation have definite deteriorating effects on materials, but, in general, their concentrations are not sufficiently strong to cause appreciable damage. The other

environments discussed require special consideration under certain conditions or in specific locations, but are generally considered to be of only minor importance as to their potential degradation of aircraft and airborne equipment.

WADC-TN-56-474 AD-110516

Hollaway Elizabeth
BIBLIOGRAPHY ON THE EFFECTS OF RADIATION,
Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio, November 1956, 8 pp. (60 refs).

The purpose of this technical note is to provide a bibliographical reference on the effects of radiation on materials used in electronic components.

WADC-TR-56-15

McGrath Joyce and Johnson R H, 1/Lt. (USAF)
THE EFFECTS OF GAMMA RADIATION ON TEXTILE MATERIALS,
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, February (1956), 27 pp.

The primary purpose of this investigation was to obtain data on the effect that exposure to high energy gamma radiation, for specific periods of time, would have on various parachute textile materials, also to determine if the use of parachute marking ink would increase or speed up the degradation of the materials.

The materials were irradiated both in the Cobalt^{60} source located in Materials Laboratory, Wright Air Development Center, WPAFB, Ohio, and the Materials Test Reactor, National Reactor Testing Station, Idaho Falls, Idaho. All materials were evaluated both before and after exposure.

The white nylon fabrics showed the greatest loss in strength after exposure for sixteen hours at a total dosage of 7.4×10^6 r (over 25% loss), while the dacron (E. I. du Pont de Nemours's fiber) fabrics retained a high percentage of strength for the same exposure (less than 7% loss). The loss in strength of both nylon and dacron fabrics marked with parachute marking ink, was no greater than for the same fabrics that were not marked with the ink.

All webbings and cords had a high percentage of loss after exposure for 18.3 hours with a total dosage of 1.7×10^8 r. In this group the nylon webbing, Spec. Mil-W-4088, Type XIII, resin treated gave the best results, with a loss of 26-28%. All types of cord showed a loss in strength of 45 to 53%.

Nylon fabric from parachutes which were exposed to varying degrees of thermal and nuclear radiation in tests at the Nevada Proving Grounds showed very slight degradation, except in areas where identification nomenclature had been stamped (Spec. Mil-I-6903 Ink, Marking, Blue). In several instances the identification area was burned or melted out in the outline of the identifying cipher or letter. In others the area was so completely damaged that identification was impossible.

WADC-TN-57-185 AD-118288

Krasnow M E, et al.
DETERMINATION OF TESTING SCHEMES FOR ANP WEAPON SYSTEM MATERIALS,
Inland Testing Laboratories, Division Cook Electric Co., Chicago, Ill., Contract No. AF33(616)-3912, May (1957), 109 pp. (100 refs).

In order to build a nuclear powered vehicle, it is necessary to build systems that will operate satisfactorily in conjunction with a nuclear environment. Before design and development testing can begin, it is necessary to determine which environments are interactive with radiation, and therefore, which environments need be combined for irradiation testing. It is the purpose of this report to define those environments which are additive and those which are interactive with a radiation environment.

WADC-TN-57-229 AD-130775

Van Arrdell P M
BIBLIOGRAPHY - FORMULATION OF AN ENVIRONMENTAL TESTING PHILOSOPHY FOR ANP WEAPON SYSTEMS,
Inland Testing Laboratories, Morton Grove, Ill., Contract No. AF33(616)-3912, June (1957), 209 pp. (5 refs).

This report is the result of a systematic review of over 10,000 documents and presents a comprehensive cataloged and cross-indexed bibliography of presently available information of Radiation Damage. Over 2000 references are compiled on all facets of Radiation Effects and Radiation Sources. It is believed that this information will provide an invaluable source for any future work contemplated in the field of Radiation Effects on Materials.

WAPD-BT-5-7

Kelleher F A
A TEST REPORT ON THE FISCHER AND PORTER SPRING BALANCED FLOAT-TYPE FLOWMETER,
Bettis Technical Review, Reactor and Plant Engineering, Westinghouse Electric Corp., Pittsburgh, Pa., Contract No. AT-(11-1)-Gen-14, December (1957), 14 pp.

The spring balanced, float-type flowmeter has shown promise as a simple, reliable means of measuring flow in primary system piping. The Fischer and Porter Company developed such an instrument under subcontract to Bettis, and the results of Bettis hydraulic testing are presented. While no reliable calibration checks are available at 500^{O}F and 2000 psi, those conclusive results obtained appear favorable, and it is expected that further tests will prove the instrument desirable for the designed purpose.

WIN-15

Pickwick Fred, Jr.
ION EXCHANGE RESIN TESTING - PART II. PERMUTIT RESINS TESTED DURING THE PERIOD FEBRUARY 1952 THRU NOVEMBER 1954,
National Lead Co., Inc., Contract No. AT-(49-6)-924, November 15, 1952, 30 pp.

This report presents the results of test work performed on samples of ion exchange resins submitted by the Permutit Company in the period February 1952 thru November 1954.

During this period, the uranium adsorption and elution properties of the Permutit resins have been observed to improve considerably.

By using early test data, the Permutit Company was able to adjust the manufacture of their resins so that later resin lots showed improved uranium adsorption and elution properties.

NOTES

RADIATION EFFECTS

No. of copies	Distribution
3	Aberdeen Proving Ground
1	Aerojet-General Corporation
1	Aerojet-General, San Ramon (IOO-880)
1	AFPR, Boeing, Seattle
3	AFPR, Lockheed, Marietta
2	Air Force Special Weapons Center
2	ANP Project Office, Convair, Fort Worth
1	Alco Products, Inc.
1	Allis-Chalmers Manufacturing Company
10	Argonne National Laboratory
1	Army Ballistic Missile Agency
3	Army Chemical Center
1	Army Chemical Center (Taras)
1	Army Chemical Corps
1	Army Medical Research Laboratory
1	Army Signal Research and Development Laboratory
1	AEC Scientific Representative, Japan
3	Atomic Energy Commission, Washington
3	Atomics International
4	Babcock and Wilcox Company (NYOO-1940)
2	Battelle Memorial Institute
4	Bettis Plant
4	Brookhaven National Laboratory
1	Brush Beryllium Company
1	BAR, Goodyear Aircraft, Akron
1	Bureau of Medicine and Surgery
1	Bureau of Ships (Code 1500)
1	Bureau of Yards and Docks
1	Carnegie Institute of Technology
1	Chicago Operations Office
1	Chicago Patent Group
2	Combustion Engineering, Inc.
1	Convair-General Dynamics Corporation, San Diego
3	Defence Research Member
1	Denver Research Institute
2	Department of the Army, G-2
3	duPont Company, Aiken
1	duPont Company, Wilmington
1	Edgerton, Germeshausen and Grier, Inc., Las Vegas
1	Frankford Arsenal
1	General Atomic Division
2	General Electric Company (ANPD)
6	General Electric Company, Richland
1	General Electric Company, St. Petersburg
1	General Nuclear Engineering Corporation
1	Gibbs and Cox, Inc.
1	Goodyear Atomic Corporation
1	Iowa State College
1	Jet Propulsion Laboratory
4	Knolls Atomic Power Laboratory
2	Los Alamos Scientific Laboratory
1	Mallinckrodt Chemical Works
1	Maritime Administration
1	Martin Company
1	Monsanto Chemical Company
1	Mound Laboratory
1	National Aeronautics and Space Administration, Cleveland
2	National Bureau of Standards
1	National Bureau of Standards (Library)
1	National Lead Company, Inc., Winchester
1	Naval Medical Research Institute
3	Naval Research Laboratory
2	New York Operations Office
1	Nuclear Development Corporation of America
1	Nuclear Metals, Inc.
1	Oak Ridge Institute of Nuclear Studies
5	Office of Naval Research
1	Office of Naval Research (Code 422)
1	Office of Ordnance Research
1	Office of Quartermaster General
1	Office of the Chief of Naval Operations
1	Ordnance Materials Research Office
1	Ordnance Tank-Automotive Command
1	Patent Branch, Washington
1	Pennsylvania State University (Blanchard)
4	Phillips Petroleum Company (NRTS)
1	Picatinny Arsenal
1	Power Reactor Development Company
3	Pratt and Whitney Aircraft Division
1	Princeton University (White)
2	Public Health Service
1	Public Health Service, Savannah
1	Rensselaer Polytechnic Institute
3	Sandia Corporation, Albuquerque
1	Sylvania Electric Products, Inc.
1	Technical Research Group
1	Tennessee Valley Authority
2	Union Carbide Nuclear Company (ORGDP)
6	Union Carbide Nuclear Company (ORNL)
1	USAF Project RAND
1	U. S. Geological Survey, Denver
1	U. S. Geological Survey, Naval Gun Factory
1	U. S. Geological Survey, Washington
1	U. S. Naval Ordnance Laboratory
1	U. S. Naval Postgraduate School
2	U. S. Naval Radiological Defense Laboratory
1	U. S. Patent Office
3	University of California, Berkeley
2	University of California, Livermore
1	University of Puerto Rico
1	University of Rochester
1	University of Rochester (Marshak)
1	Watertown Arsenal
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