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DESCRIPTION OF THE REACTOR AND EXPERIMENTAL FACILITIES

Very briefly, by way of introduction, the Battelle Research Reactor (BRR) is a modified pool reactor, light water-moderated and -reflected. The BRR is presently operating at 2000 kw (t). The over-all dimensions of the pool are about 20 ft x 40 ft x 28 ft deep. The pool narrows down at one end to form a stall where a thermal column and six beam tubes pierce the barytes concrete pool wall. Two bridges rool on rails along the sides of the pool. One of these, the instrument bridge, is used to suspend experiments near the core and is presently occupied by a high temperature gas-cooled loop. The reactor core and in-core portions of the control system are suspended on a tower from the second bridge.

The core is made up of 32-10 plate MTR-type fuel elements. The array is a 6 x 6 arrangement with two elements missing inside the core to form high-flux irradiation positions and two missing at the open face to accommodate the loop. Six of the elements are special control rod assemblies that contain four boron-carbide shim-safety rods and a stainless steel regulating rod. The sixth control rod element does not contain a control rod but rather is used as another high flux irradiation hole.

The core is cooled by pumping pool water down through the elements at the rate of 2000 gallons per minute. The primary coolant passes through the tubes of a U-tube heat exchanger and is returned to the pool through a 2000 gallon holdup tank located on the pool floor; 20 gallons per minute of the primary coolant is by-passed through a filter and mixed-bed demineralizer. The secondary coolant is tap water and it is circulated at 800 gallons per minute through the shell side of the heat exchanger and a spray cooling tower.

Experimental facilities include four six-inch and two eight-inch beam tubes, and a thermal column with a 4-1/2 ft square horizontal access and 3-1/2 ft diameter vertical access. In-core irradiation facilities include two holes about 3 x 3 in. in cross section and a third 1 x 3 in. A hydraulic irradiation facility which can be positioned in any empty grid plate hole is also available for short exposures. In addition, about 700 sq. in. of core face are open for irradiations.

Unperturbed thermal neutron fluxes up to 4×10^{13} n/cm^2-sec are available in the in-core holes. The highest flux available at the faces of the core is about 1.5×10^{13} thermal neutrons/cm^2-sec.

PROCEDURES AND OPERATING EXPERIENCE

The BRR was initially critical late in October of 1956. After about five months of preliminary experiments with the reactor, routine operation at a power level of 1000 kw was begun and the experimental facilities were made available to research projects at Battelle. Two years later, in March of 1959, the power level was increased to 2000 kw and routine operation has since continued at that power level.

The operation and maintenance of the reactor is the responsibility of the Operating Supervisor. He is a graduate physicist with several years training in reactor operations.

In our operating procedures, an experimenter planning to use radiation from the reactor is instructed to contact the Operating Supervisor when the experimental program is initiated. Space is assigned based on experimental requirements and a member of the Reactor Physics Division is appointed as technical advisor. A report containing all pertinent information including an analysis of the hazards is prepared by the experimenter aided by the technical advisor. In general, this report should state the purpose of the experiment, give a detailed description of the apparatus involved, discuss the hazards attendant with routine operation of the experiment, describe the maximum credible accident, and outline precautions taken to minimize the probability of an accident. The results of any out-of-pile tests should be included. Usually, experiments are accepted only for in-pile operation; any tests which can be conducted out-of-pile, such as integrity at high temperatures and pressures, must be completed before the irradiation.

This report which varies in length from several paragraphs to many pages depending on the complexity of the experiment is submitted to the Operating Supervisor. The Operating Supervisor has the authority to approve experiments to go into the reactor without referring them to a review committee. In practice he does this only with repetitive routine or simple experiments which he is confident are safe and for which he is willing to assume full responsibility without review.

If an experiment has novel features or is potentially hazardous because of some reaction on which he is not expert, he requests a review and evaluation by the Reactor Safety Committee. The Committee submits a written recommendation to the Operating Supervisor who along with his supervisors decides if the experiment can be run or it should be modified. The final decision is always with "line" personnel.

In evaluating the hazards connected with an experiment, possible effects on the health and safety of the general public and operating personnel, possible damage to the reactor, and possible damage to other experiments are considered, in order. Frequently, shutting down an experiment in the event it malfunctions is sufficient to assure continued safe operation. Occassionally the experiment has characteristics which require that it be interlocked with the reactor scram. Since the BRR has only one mode of emergency shutdown--a full scram--the effects of a scram on other experiments must be considered. The experimenter must demonstrate that instrumentation relied up on to shutdown either an experiment or the reactor is fail-safe and functions automatically.

During the nearly three years of routine operation, these procedures have proved workable although minor modifications have been required from time to time. One factor which has affected changes in the procedures has been the increase in the number of experiments in the reactor at a given time. The increase in experimental activity was first reflected in a change in the length of the operating cycle. At first, the cycle consisted of six days of continuous operation followed by one day of shutdown. As the experimental load increased it became impossible to complete the necessary maintenance and experimental work in one shutdown day so the cycle was lengthened to 12 days of continuous operation followed by two days of shutdown. At the present time, activity on shutdown days has reached the point where another change in operating cycle is being considered.

There are several reasons for the increased demand for time during the shutdown period. Reactor maintenance demands have increased because of the length of time the reactor has been in operation and because of the higher operating power level. The increased maintenance requirement is particularly noticeable in the in-core components of the control system: the ion chambers and safety rod magnets. The probability of these components failing due to radiation damage increases with time and with intensity of the radiation and more frequent preventive maintenance is necessary to detect and repair such failures before they cause down time.

Also, an increasing amount of time is required to conduct experiments which need low power operation or which must be run at several different power levels. The only time available for this type of operation is, of course, the shutdown period. In addition, a certain amount of time during the shutdown period is required by the operating staff to perform routine flux measurements, core flux plots for fuel burnup calculations, and control rod calibrations. However, most operations during shutdown periods involve experimental programs and result from requirements imposed on new experiments to be installed in the reactor. For each experiment, prior to continuous in-pile operation, the reactivity effect of the experiment must be determined and the characteristics of the experiment must be checked out at full power. If calculations indicate that an experiment may use a significant fraction of the reactivity allotted for in-pile experiments a measurement of reactivity effect is usually performed on a nuclear mockup before construction of the actual experiment begins. The checkout run is required so that routine operation will not be delayed unnecessarily to remove an experiment that does not function as it should.

The increasing experimental load also introduces new problems, both administrative and technical, which are directly connected with the operation of the reactor. These include scheduling experiments, determining interactions among experiments, and evaluating the effects of a large number of experiments on the safe operation of the reactor. The last category includes not only the effect that a malfunction of the experiment may have on safe operation but also the effect of an error by personnel operating the experiment.

As mentioned earlier the facilities of the BRR are available to all the research divisions at Battelle and in this sense the reactor operates as a service facility for the rest of the Institute. Many of these divisions and their personnel have had considerable experience in the use of reactors for experimental purposes while others have not. In either case, when a research proposal is prepared a member of the reactor operating staff is consulted to assure that the proposed program is feasible from the standpoints of desired radiation intensities, physical size, and available reactor space. If the conditions of the program can be met, at the BRR a space commitment is made that reserves space in the reactor for a particular period. This commitment is held for a period of 30 days; if at that time the proposal has not been accepted, the space reservation may be cancelled or rescheduled on a tentative basis.

One problem encountered in effective scheduling involves interactions among experiments which may cause undesirable flux perturbations affecting some or all of those involved. In this respect, the advantages of a high power density (flux) are offset somewhat by the small physical size of the core. We find that it is rarely advisable to schedule two experiments closely adjacent to each other if flux requirements are critical. This, of course, requires that scheduling be done carefully and kept up-to-date since it is an empirically-determined fact that whatever the available flux, experimenters will want at least a factor of two higher flux. Fortunately, at a power level of 2000 kw only small changes occur in flux from cycle to cycle due to fuel burnup. Over a period of several cycles, the greatest changes in flux level in any given region occur during the first two days of the cycle when xenon poisoning is increasing rapidly.

Our experience has shown that experiments are operated most efficiently by the people who design and build them. For this reason, most experiments are operated by personnel not connected with reactor operations. This system has the added, and perhaps more important advantage, of divorcing reactor operation from experiment operation to the extent that the safe operation of the reactor is not compromised for the sake of an experiment. One disadvantage of this type of operation is that initially each new experiment brings with it personnel who are unfamiliar with the operating rules of the reactor, and, in some cases, with the principles of radiation safety. Training these people is the responsibility of the operating staff and health physics personnel and a formal curriculum has been established. Some time ago the number of experimenters became so large that it became necessary to have some method of identifying quickly those who had finished their training and were authorized free access to the building. This was done by color coding radiation film badges. Since all personnel who have reason to enter the building, with the exception of casual visitors, are assigned a film badge, it is now a simple matter to exercise control over those who enter the building. Those personnel who are not granted free access must be escorted and work under supervision until such time as they have been trained sufficiently to deserve a free access badge.

POWER INCREASE TO TWO-MEGAWATTS

Two operational problems have been encountered since the power level was increased to two megawatts. The first is the disposal of contaminated waste water from the regeneration of the primary coolant demineralizer. Although we anticipated an increase in the radioactivity of the waste water with the higher flux in the core, a considerable portion of the increase is attributed to the increasing number of experiments and associated hardware stored in the pool. During the first two years of operation it was possible to release the waste water with reasonably low dilution at activity levels well below maximum permissible concentrations. At present, dilution is impractical and other means of disposal have been investigated.

Since the principle contaminant was zinc-65, chemical precipitation on a laboratory scale proved satisfactory. However, it didn't prove practical on a large scale because of the lack of space for settling tanks and equipment required to filter the precipitate. The presence of about 0.1 lb/gal of NaCl in the waste makes concentration by ion exchange very expensive. Finally, a combination distillation-ion exchange system was devised to handle the problem. In this system the waste water is distilled in ordinary laboratory stills and the distillate passed through a small cartridge demineralizer. The effluent water is sufficiently decontaminated that it can be released if necessary. However, the concentration of dissolved solids is also low enough so that the water can be returned to the reactor pool to serve as make up water. One feature of the system which may ultimately limit its use is the effect on still efficiency of the increasing concentration of salt in the feed water. In the operation of the system so far this problem has been avoided by preventing complete concentration, since the immediate concern has been to dispose of as much water as possible.

The other problem that has appeared in recent months is an increase in air activity in the reactor building. The increase first became noticeable in the autumn months of 1959. Actually, it is not the increase itself that is of concern since this is to be expected at the higher power level, but rather the fact that the background has increased which could effect detection of an accidental release of activity. The activity as identified by its gamma spectrum and half-life appears to be 32 minute cesium 138. However, the parent fission product, 17 min xenon-138, has not been detected. From activity measurements the concentration of cesium-138 has been calculated to be 2×10^{-8} μc/ml and although no maximum permissible concentration is listed for this nuclide, this concentration is not considered harmful because of its short half-life. In order to reduce the background level, part of the pool surface has been covered with "styrafoam". This cover has decreased the air activity to the original level and also serves the additional function of reducing evaporation losses from the pool.

REACTOR IRRADIATIONS

Since the reactor began routine operation it has supplied radiations for a large number of research programs. While all have points of interest, time permits only the mention of a few which have particular interest from an operating viewpoint.

The first of these is the gas-cooled loop. Initially sponsored by the Army Reactors Branch of the USAEC, the loop is now officially designated the BMI-GCRE loop and is operated under the sponsorship of Aerojet-General Nucleonics.

The entire loop, with its test section, blower, heat exchanger and instrumentation is mounted on the reactor's instrument bridge. In all, 5 elements have undergone tests in the loop for an accumulated operating time of 3000 hours. From a reactor operation viewpoint the loop is unique in that upon completion of a test the loop can be removed from the core by rolling the instrument bridge to the back of the pool with no more than ten minutes' delay in reactor operations. The element under test can be transferred in a completely dry condition under water from the loop to a transfer cask with no interference at all to the reactor.

Another interesting series of experiments has been the high-temperature capsule irradiations done in connection with the pebble-bed reactor concept under development by Sanderson and Porter. Four capsules have been irradiated in the high flux in-core irradiation positions and two in lower flux positions at the core face. The purpose of most of these experiments has been to determine the ability of various types of fueled graphite spheres to retain gaseous fission products. Three of the capsules have been designed to allow a carrier gas to sweep over the spheres during irradiation and carry any gaseous fission products to an out-of-pile analysis system.

Physically, the largest experiment in operation at the reactor is the Shielding Studies Area sponsored by the General Electric-Aircraft Nuclear Propulsion Department. This facility consists of a 4-kg fission plate located at the horizontal access to the thermal column. Shielding slabs and detectors are suspended in a 15 ft square water-filled shielding tank adjacent to the fission plate. Instruments and detectors are available to measure gamma and fast neutron spectra and dose-rate throughout the tank, and include a multicrystal gamma spectrometer and proton recoil fast neutron spectrometer. One relaxing aspect of the experiment, so far as reactor operations is concerned, is that the thermal column provides such loose coupling from experiment to core that operation of the experiment has no noticeable effect on the core.

The largest core irradiations that have been performed are two encapsulated diesel engine cylinder liners for the Fairbanks-Morse Company. These were 5 ft long and 15 in. in diameter; they were supported by stands on the pool floor and rotated during irradiation by a motor located at the pool surface.

CONCLUDING REMARKS

The BRR has operated some 13,000 hours since routine operation commenced without a major incident or accident. This operating time represents an average of 85 per cent of total scheduled time and includes some 73,000 experiment operating hours.

While the increasing number of experiments brings with it an increasing number of operational problems, the solution of these problems can only add to the experience of the reactor operator and must ultimately result in more efficient and productive use of the reactor as a unique research tool.