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DNA 6323F

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OPERATIONS
MANDREL & GROMMET

EVENTS
MINUTE STEAK, DIESEL TRAIN, DIANA MIST, MINT LEAF, HUDSON MOON, DIAGONAL LINE, and MISTY NORTH

12 September 1969 to 2 May 1972

[redacted]

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United States Underground Nuclear Weapons Tests
Underground Nuclear Test Personnel Review

DNA 6323

Prepared by Field Command, Defense Nuclear Agency

DARE#
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This report is a personnel-oriented history of DOD participation in underground nuclear weapons testing during OPERATIONS MANDREL and GROMMET, test events MINUTE STEAK, DIESEL TRAIN, DIANA MIST, MINT LEAF, HUDSON MOON, DIAGONAL LINE, and MISTY NORTH, 12 September 1969 to 2 May 1972 and is the fourth in a series of historical reports which will include all DOD underground nuclear weapons tests and all DOE underground nuclear weapons tests with significant distribution from 1962 forward. In addition to these historical volumes, a restricted distribution volume will identify all DOD participants (military, civilian and DOD contractors) and will list their radiation dosimetry data.

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Nevada Test Site (NTS)	MINUTE STEAK	DIESEL TRAIN
Underground Test (UGT)	DIANA MIST	MINT LEAF
HUDSON MOON	DIAGONAL LINE	MISTY NORTH

SUMMARY

Seven Department of Defense (DOD)-sponsored underground test events were conducted from 12 September 1969 to 2 May 1972 to study weapons effects. Two were shaft-type and five were tunnel-type nuclear tests. The following table summarizes data on these events:

OPERATION	MANDREL					GROMMET	
TEST EVENT	MINUTE STEAK	DIESEL TRAIN	DIANA MIST	MINT LEAF	HUDSON MOON	DIAGONAL LINE	MISTY NORTH
DATE	12 Sep 69	5 Dec 69	11 Feb 70	5 May 70	26May70	24 Nov 71	2 May 72
LOCAL TIME (hours)	1102 PDT	0900 PST	1115 PST	0830 PDT	0715 PDT	1215 PST	1215 PDT
NTS LOCATION	U11i	U12e.11	U12n.06	U12t.01	U12e.12	U11g	U12n.05
TYPE	Shaft	Tunnel	Tunnel	Tunnel	Tunnel	Shaft	Tunnel
DEPTH (feet)	867	1,386	1,319	1,330	1,386	867	1,234
YIELD*	Low	Low	Low	Low	Low	Low	Low

* LOW INDICATES LESS THAN 20 KILOTONS

Releases of radioactive effluent to the atmosphere were detected both onsite and offsite after MINT LEAF, a tunnel-type event and DIAGONAL LINE, a shaft-type event. Releases of radioactive effluent were detected only within the confines of the Nevada Test Site (NTS) after the HUDSON MOON and MINUTE STEAK events. No release of radioactive effluent was detected onsite or offsite after the DIESEL TRAIN, DIANA MIST, and MISTY NORTH test events.

As recorded on Area Access Registers, 9,480 individual entries to radiation exclusion areas were made after the above DOD test events. Of this number, 1,692 were by DOD-affiliated personnel (including military, DOD civilian, and DOD contractor). The remainder were United States Atomic Energy Commission (AEC)*, other government agency, and other contractor personnel.

The average gamma radiation exposure per entry for all participants was 20 mR. The average gamma radiation exposure per entry for DOD-affiliated participants was 27 mR. The maximum exposure of a non-DOD participant during an entry was 715 mR. The maximum exposure of a DOD-affiliated participant was 545 mR. These maximum exposures occurred on 12 October 1970 and 3 December 1970, respectively, after the HUDSON MOON event.

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* The U.S. Atomic Energy Commission became the U.S. Energy Research and Development Administration (ERDA) on 19 January 1975. The U.S. Department of Energy (DOE) succeeded ERDA in October 1977.

PREFACE

The United States Government conducted 194 nuclear device tests from 1945 through 1958 during atmospheric test series at sites in the United States and in the Atlantic and Pacific Oceans. The United States Army's Manhattan Engineer District (MED) implemented the testing program in 1945, and its successor agency, the AEC, administered the program from 1947 until testing was suspended by the United States on 1 November 1958.

Of the 194 nuclear device tests conducted, 161 were for weapons related or effects purposes, and 33 were safety experiments. An additional 22 nuclear experiments were conducted from December 1954 to February 1956 in Nevada. These experiments were physics studies using small quantities of fissionable material and conventional explosives.

President Eisenhower had proposed that test ban negotiations begin on 31 October 1958, and had pledged a one-year moratorium on United States testing to commence after the negotiations began. The Conference on Discontinuance of Nuclear Weapons Tests began at Geneva on 31 October 1958, the U.S. moratorium began on 1 November, and the AEC detected the final Soviet nuclear test of their fall series on 3 November 1958. Negotiations continued until May 1960 without final agreement. No nuclear tests were conducted by either nation until 1 September 1961 when the Soviet Union resumed nuclear testing in the atmosphere. The United States began a series of underground tests in Nevada on 15 September 1961, and U.S. atmospheric tests were resumed on 25 April 1962 in the Pacific.

The United States conducted several atmospheric tests in Nevada during July 1962, and the last United States atmospheric nuclear test was in the Pacific on 4 November 1962. The Limited Test Ban Treaty, which prohibited tests in the atmosphere, in outer space, and underwater, was signed in Moscow on 5 August 1963. From resumption of United States atmospheric testing on 25 April 1962 until the last atmospheric test on 4 November 1962, 40 weapons related and weapons effects tests were conducted as part of Pacific and Nevada atmospheric test operations. Underground tests, resumed on 15 September 1961, have continued on a year-round basis through the present time.

In 1977, 15 years after atmospheric testing stopped, the Center for Disease Control (CDC)* noted a possible leukemia cluster within the group of soldiers who were present at the SMOKY test event, one of the Nevada tests in the 1957 PLUMBBOB test series. After that CDC report, the Veterans Administration (VA) received a number of claims for medical benefits filed by former military personnel who believed their health may have been affected by their participation in the nuclear weapons testing program.

In late 1977, DOD began a study to provide data for both the CDC and the VA on radiation exposures of DOD military and civilian participants in atmospheric testing. Early in 1978 during hearings by the U.S. House of Representatives Subcommittee on Health and Environment, the DOD agreed to give top priority to gathering and providing those data. Those efforts have progressed to the point where a number of volumes describing DOD

*The Center for Disease Control was part of the U.S. Department of Health, Education, and Welfare (now the U.S. Department of Health and Human Services). It was renamed The Centers for Disease Control on 1 October 1980.

participation in atmospheric tests have been published by the Defense Nuclear Agency (DNA) as the executive agency for DOD.

On 20 June 1979, the United States Senate Committee on Veterans' Affairs began hearings on Veterans' Claims for Disabilities from Nuclear Weapons Testing. In addition to requesting and receiving information on DOD personnel participation and radiation exposures during atmospheric testing, the Chairman of the Senate Committee expressed concern regarding exposures of DOD participants in DOD-sponsored and DOE underground test events.

The Chairman requested and received information from the Director, DNA, in an exchange of letters through 15 October 1979 regarding research on underground testing radiation exposures. In early 1980, DNA initiated a program to acquire and consolidate underground testing radiation exposure data in a set of published volumes similar to the program under way on atmospheric testing data. This volume is the fourth of several volumes regarding participation and radiation exposures of DOD military and civilian participants in underground nuclear test events.

SERIES OF VOLUMES

Most volumes in this series discuss DOD-sponsored underground test events, in chronological order, after presenting introductory and general information. These volumes cover all except one category of underground test events identified as DOD-sponsored in Announced United States Nuclear Tests, published each year by the DOE Nevada Operations Office, Office of Public Affairs. The category of events not covered was conducted as nuclear test detection experiments in a program named VELA Uniform. Generally, significant exposure (above the 30 mR minimum detectable amount for film badges) of participants to radiation did not occur during tests in this category.

An additional volume discusses general participation of DOD personnel in DOE-sponsored underground test events, with specific information on those events which released radioactive effluent to the atmosphere and where exposures of DOD personnel were involved.

A separate set of books comprising one volume is a census of DOD personnel and their radiation exposure data. Distribution of this volume necessarily is limited by provisions of the Privacy Act.

METHODS AND SOURCES USED TO PREPARE THE VOLUMES

Information for these volumes was obtained from several locations. Security-classified documents were researched at Headquarters, DNA, Washington, DC. Additional documents were researched at Field Command (FC), DNA, the Air Force Weapons Laboratory (AFWL) Technical Library, and Sandia National Laboratories (SNL) in Albuquerque, New Mexico. Most of the radiation measurement data were obtained at the DOE, Nevada Operations Office (DOE/NV), and its support contractor, the Reynolds Electrical & Engineering Company, Inc. (REECo), in Las Vegas, Nevada.

Unclassified records were used to document underground testing activities when possible, but, when necessary, unclassified information was extracted from security-classified documents. Both unclassified and classified documents are cited in the List of References at the end of each volume. Locations of the reference documents also are shown. Copies of most of the unclassified references have been entered in the records of the Coordination and Information Center (CIC), a DOE facility located in Las Vegas, Nevada.

Radiation measurements, exposure data, event data, and off-site reports generally are maintained as hard copy or microfilm at the REECo facilities adjacent to the CIC, or as original hard copy at the Federal Archives and Records Center, Laguna Niguel, California. The Master File of all available personnel exposure data for nuclear testing programs on the continent and in the Pacific from 1945 to the present also is maintained by REECo for DOD and DOE.

ORGANIZATION OF THIS VOLUME

A Summary of this test event volume appears before this Preface and includes general objectives of test events, characteristics of each test event, and data regarding DOD participants and their radiation exposures.

An Introduction following this Preface discusses reasons for conducting nuclear test events underground, the testing organization, the NTS, and locations of NTS underground testing areas.

A chapter titled Underground Testing Procedures explains the basic mechanics of underground testing, purposes of effects experiments, containment features and early containment problems, tunnel and shaft area access requirements, industrial safety and radiological safety procedures, telemetered radiation exposure rate measurements, and air support for underground tests.

A chapter on each test event covered by this volume follows iN chronological order. Each test event chapter contains an event summary, a discussion of preparations and event operations, an explanation of safety procedures implemented, and listings of monitoring, sampling, and exposure results.

Following the event chapters are a Reference List and appendices to the text including a Glossary of Terms and a List of Abbreviations and Acronyms.

CONVERSION TABLE

CONVERSION FACTORS FOR U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

MULTIPLY ——>	BY ——>	TO GET
TO GET <——	BY <——	DIVIDE
curie (C)	3.700 000 X E+1	*giga becquerel (GBq)
degree (angle)	1.745 329 X E-2	radian (rad)
degree Fahrenheit	$t_K = (t°f + 459.67)/1.8$	degree kelvin (K)
foot	3.048 000 X E-1	meter (m)
gallon (U.S. liquid)	3.785 412 X E-3	$meter^3$ (m^3)
inch	2.540 000 X E-2	meter (m)
kilotons (kt)	4.183	terajoules
mile (international)	1.609 344 X E+3	meter (m)
ounce	2.834 952 X E-2	kilogram (kg)
rad (radiation absorbed dose)	1.000 000 X E-2	**Gray (Gy)
roentgen (R)	2.579 760 X E-4	coulomb/kilogram (c/kg)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.

**The Gray (Gy) is the SI unit of absorbed radiation.

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CHAPTER 1

INTRODUCTION

The first United States nuclear detonation designed to be fully contained underground was the RAINIER tunnel event conducted by the University of California Radiation Laboratory (UCRL) for the AEC in Nevada on 19 September 1957. This was a weapons related experiment with a relatively low yield of 1.7 kilotons (kt). The second tunnel event with a significant nuclear yield was a safety experiment on 22 February 1958 also conducted in Nevada by UCRL for AEC. This experiment, the VENUS event, resulted in a yield of less than one ton. These two tunnel events, and five additional underground safety experiments with zero or only slight yields, were the beginning of the United States underground nuclear testing program, currently the only type of nuclear detonation testing permitted by treaty. The first DOD-sponsored underground nuclear weapons effects test was the 5.7 kt HARD HAT event conducted by the Defense Atomic Support Agency (DASA) on 15 February 1962 in Nevada.

1.1 HISTORICAL BACKGROUND

While technical conferences between the United States and the Soviet Union on banning nuclear detonation tests continued, and concern regarding further increases in worldwide fallout mounted, a number of nuclear tests were conducted underground during 1958 in Nevada. Prior to the United States testing moratorium, six safety experiments in shafts, five safety experiments in tunnels, and four weapons-related tests in tunnels were conducted by user laboratories. Radioactive products from several of these tests were not completely contained underground. Containment of nuclear detonations was a new engineering challenge. Understanding and solving the majority of containment problems would require years of underground testing experience.

When the United States resumed testing on 15 September 1961, the first 32 test events were underground, including a cratering experiment with the device emplaced 110 feet below the surface. The DOMINIC I test series in the Pacific and the DOMINIC II test series in Nevada (also called Operation SUNBEAM by DOD) during 1962 were the last atmospheric nuclear detonation tests by the United States.

The commitment of the United States to reduce levels of worldwide fallout by refraining from conducting nuclear tests in the atmosphere, in outer space, and underwater was finalized when the Limited Test Ban Treaty with the Soviet Union was signed on 5 August 1963.

1.2 UNDERGROUND TESTING OBJECTIVES

The majority of United States underground tests have been for weapons related purposes. New designs were tested to improve efficiency and deliverability characteristics of nuclear explosive devices before they entered the military stockpile as components of nuclear weapons.

Safety experiments with nuclear devices also were conducted by user laboratories in addition to weapons related tests. These experiments tested nuclear devices by simulating detonation of the conventional high explosives in a manner which might occur in an accident during transportation or storage of weapons.

Weapons effects tests, sponsored by the DOD, were conducted to determine the vulnerability or survivability of military systems or components when exposed to one or more of the effects of a nuclear detonation. The nuclear devices for these tests were provided by the AEC weapons development laboratories and were designed to be similar to nuclear components used in nuclear weapons. Actual weapon configurations were used in a few test events. Military systems, structures, materials, electronic experiments, and other related experiments were provided by DOD and AEC agencies. Many of these tests were very complex and involved greater numbers of participants than other categories of tests previously mentioned. Personnel from DASA, other government organizations, and DOD contractor agencies, as well as personnel from user laboratories and contractors, were involved.

Some tests were designed to study the response of hardened structures or geologic formations to shock waves generated by nuclear detonations. Many tests were designed to study the response of military components to effects of radiation produced by nuclear weapons. Such tests required a direct line of sight between the nuclear device and the experiments. Many of the radiation effects tests required the simulation of high altitude (up to exoatmospheric) conditions. These tests involved installation of experiments inside large steel line-of-sight (LOS) pipes hundreds of feet in length, with maximum diameters of several feet. Large vacuum pumps were utilized to reduce pressure inside the pipes to the desired level.

DOD weapons effects tests MINUTE STEAK, 12 September 1969, to MISTY NORTH, 2 May 1972, conducted during Operation MANDREL and Operation GROMMET are discussed in this volume. No DOD tests were executed during Operation EMERY (1 July 1970 to 30 June 1971) although field operations were in process in Nevada during this period for the two tests which were actually executed during Operation GROMMET.

1.3 DOD TESTING ORGANIZATIONS AND RESPONSIBILITIES

Administering the underground nuclear testing program was a joint AEC-DOD responsibility. The similar nature of the AEC-DOD organizational structure is shown in Figure 1.

1.3.1 Defense Nuclear Agency

Headquarters of the Defense Nuclear Agency is located near Washington, D.C., and is composed of personnel from each of the Armed Services and civilian DOD employees. It was originally established as the Armed Forces Special Weapons Project (AFSWP) to assume residual functions of the MED, through issuance of a joint Army-Navy memorandum, dated 29 January 1947, which was retroactive to 1 January 1947 (when the AEC was activated). The responsibility for DOD nuclear weapons effects testing was assigned to AFSWP. The National Security Act of 1947 had become law when the Secretary of Defense issued a memorandum on 21 October 1947 to the three Service Secretaries confirming the previous directive of 29 January, and thus, AFSWP officially represented all of them. AFSWP was charged with providing nuclear weapons support to the Army, Navy, and Air Force. As originally chartered, AFSWP was directly responsible to each of the three Service Chiefs. In 1951, the Air Force Special Weapons Center (AFSWC) located at Kirtland Air Force Base (KAFB), Albuquerque, New Mexico, was assigned by DOD the responsibility to provide specific support to the AEC for continental nuclear testing (see Section 1.3.2). This command was not directly related to AFSWP; however, the two organizations coordinated several support tasks.

By issuance of General Order No. 2, Headquarters, DASA, dated 6 May 1959, AFSWP was redesignated the Defense Atomic Support Agency. Under its new charter, DASA was responsible to

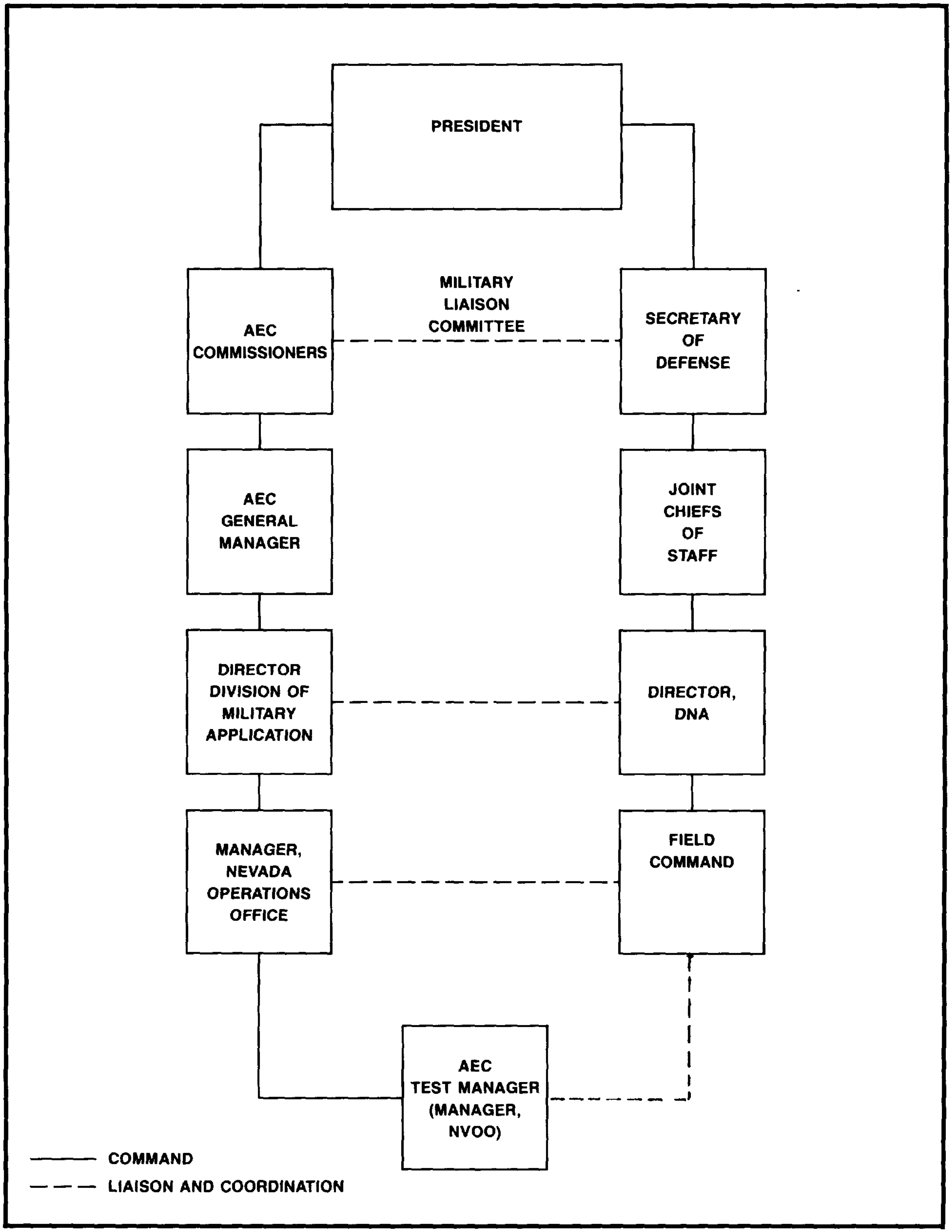


Figure 1. Federal government structure for continental nuclear tests (in 1972)

the Secretary of Defense through the Joint Chiefs of Staff. DASA's five major areas of responsibility for the DOD included:

1. staff assistance to the Office of the Secretary of Defense, through the Joint Chiefs of Staff;

2. research in weapons effects;

3. atomic tests;

4. weapons related tests; and

5. assistance to the Services.

Responsibilities of Headquarters, DASA (HQ/DASA) included providing consolidated management and direction for the DOD nuclear weapons effects testing programs, while technical direction and management of field operations of DOD nuclear weapons effects testing activities were delegated to Field Command, DASA (FC/DASA), located at Sandia Base (now part of KAFB) in Albuquerque, New Mexico. From 6 May 1959 until 1 July 1964 the Weapons Effects Tests Group (WETG) of FC/DASA was responsible for nuclear weapons effects testing and seismic detection research responsibilities (VELA UNIFORM) for the Director, DASA. This organization maintained close liaison with the AEC/Nevada Operations Office (AEC/NVOO). Personnel from FC/DASA became the military members of the joint AEC-DOD testing organization at the Nevada Test Site (NTS) and at other continental United States test locations. Participation of DOD agencies and their contractors in nuclear field tests was coordinated and supported by FC/DASA. On 1 July 1964 the testing organization in Albuquerque was designated as Weapons Test Division (WTD), a division of HQ/DASA. On 1 August 1966, WTD was changed to Test Command (TC/DASA), a separate command under HQ/DASA, but it remained in Albuquerque. The responsibilities for technical direction and management of field operations for nuclear weapons effects tests remained in effect during these changes in organization. During this period, WTD and TC maintained an engineering and support branch (designated Nevada Branch) at the NTS and a liaison office at AEC/NVOO. The Nevada Branch maintained liaison with AEC/NVOO and supervised FC/DASA activities at NTS. On 12 May 1970, the Commander, FC/DASA assumed additional command of TC/DASA.

On 29 March 1971 (effective 1 July 1971), the Deputy Secretary of Defense directed the reorganization of DASA as a result of cutbacks recommended by the "Blue Ribbon Panel" survey of agency activities. In his Executive Memorandum, DASA was retained as a defense agency under the new title, "Defense Nuclear Agency." On 1 July 1971, FC/DASA was redesignated as FC/DNA and TC/DASA became TC/DNA. While the responsibilities and manning levels at Field Command were reduced during this transition, Test Command remained essentially the same.

On 1 January 1972, TC/DNA was disestablished and personnel were transferred to FC/DNA. The responsibilities for technical direction and management of field operations for nuclear weapons effects tests were transferred to the newly-formed Test Directorate (Field Command Test-FCT) of FC/DNA. The Nevada Branch of TC was changed to the Test Construction Division of Test Directorate (FCTC) and the responsibility for the liaison office at AEC/NVOO was transferred to FCTC (see Figure 2).

1.3.2 Air Force Special Weapons Center Support

The commander of AFSWC was requested to provide air support to the Nevada Test Site Organization (NTSO) during nuclear tests at NTS. Direct support was provided by the Nuclear Test Directorate, the Special Projects Division, and the 4900th Air Base Group of AFSWC. The 4900th Air Base Group provided aircraft for shuttle service between KAFB, New Mexico, and Indian Springs

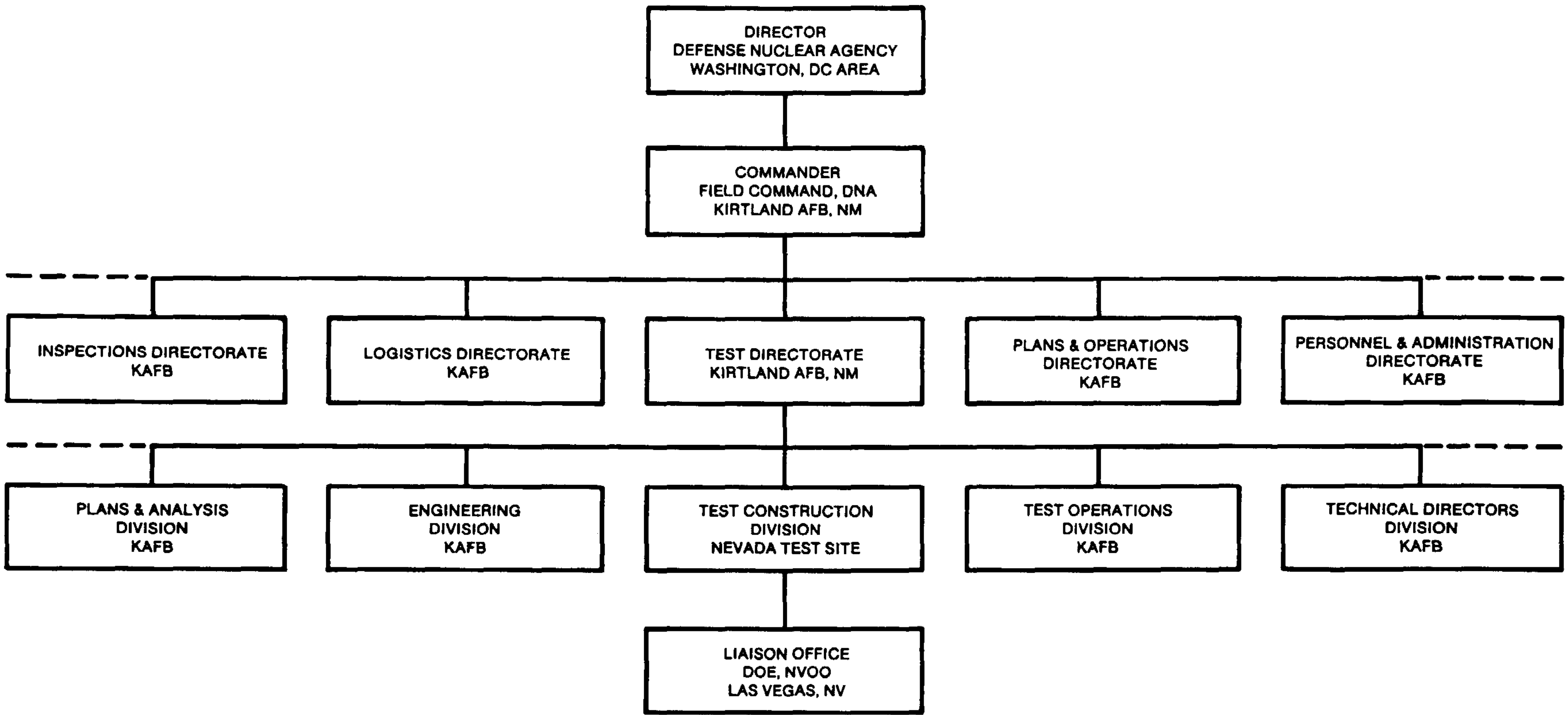


Figure 2. Partial organization chart of Field Command, Defense Nuclear Agency (in 1972)

Air Force Auxiliary Field (ISAFAF) in Nevada. The 4900th also provided aircraft and crews to perform low-altitude cloud tracking, radio relay support, and courier missions.

Other Air Force organizations providing support to the NTSO under AFSWC control on a temporary basis were as follows:

1. Elements of the 1211th Test Squadron (Sampling), Military Airlift Command, McClellan AFB, were detached to ISAFAF. Their primary task was cloud sampling. Personnel from this unit also assisted NTSO radiological safety personnel in providing support at ISAFAF, including decontamination of crews, equipment, and aircraft.

2. Elements of the 4520th Combat Crew Training Wing, Tactical Air Command, Nellis AFB, Nevada, provided support functions, such as housing, feeding, and logistics, to the units operating from ISAFAF and Nellis AFB. In addition, they conducted security sweep flights over NTS and control tower operations, fire-fighting, and crash rescue services at ISAFAF. They also maintained and provided equipment for the helicopter pad at the NTS Control Point (CP) and other helicopter pads at each Forward Control Point (FCP).

3. The 55th Weather Reconnaissance Squadron, Military Airlift Command, McClellan AFB, provided one aircraft and crew to perform cloud tracking.

4. The Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson AFB, provided aircraft and crews to perform technical projects.

1.3.3 AEC-DOD Relationships

DOD was responsible for establishing criteria for nuclear weapons, developing and producing delivery systems, developing nuclear weapons plans and forces, providing defense against nuclear attack, and obtaining nuclear weapons effects data through DNA. The AEC was responsible for research and development, production, and supply of nuclear weapons to the Armed Forces in quantities and types specified by the Joint Chiefs of Staff. Quantities and types of weapons were described in the Nuclear Weapon Stockpile Memorandum signed jointly by the Secretary of Defense and the Chairman of the Atomic Energy Commission and approved by the President. The AEC, in association with DOD, also was responsible for providing field nuclear test facilities in the continental United States and overseas.

The principal points of field coordination between the AEC and the DOD were at AEC/NVOO in Las Vegas and at NTS. From the beginning of the DOD underground nuclear weapons effects test program (first test was HARD HAT in February 1962) until the present, Field Command (or Test Command) was the fielding agency for DOD/DNA and served as primary point of contact with AEC/NVOO. AEC/NVOO and its predecessors represented AEC in the field for all continental tests. The AEC nuclear weapons development laboratories fielded underground tests as part of the weapons development program; DNA fielded underground tests at NTS to obtain weapons effects data. Since the NTS was an AEC installation, the Manager, AEC/NVOO was responsible for all operations there.

For each DOD-sponsored test, HQ/DNA coordinated requirements with the military services. Requirements for testing to determine the nuclear vulnerability or hardening of military systems or components were submitted by these organizations. As part of long range underground nuclear weapons effects test planning, HQ/DNA developed a schedule of specific events designed to satisfy military requirements. One or more of the DOD agencies were cosponsors and, usually, active participants in each DOD underground test. The initial approval of DOD experiments and the selection of the nuclear source (device) for each test was accomplished at the HQ/DNA level. A request for the appropriate nuclear device and associated support was forwarded by HQ/DNA to the Director, Division of Military Application, AEC. The AEC assigned one or more of the weapons development laboratories to provide the device support.

Following initial planning, the responsibility for detailed planning, engineering, fielding, execution, and reporting was assigned to FC/DNA. Field Command formed a test group staff for each test. The technical director (normally a military officer assigned to FC/DNA or AFWL) was appointed by HQ/DNA. The test group director and other members of the staff were appointed by FC/DNA. The test group engineer normally was selected from FCTC, Nevada Branch.

The test group staff developed detailed test plans and schedules. Engineering and construction plans were developed by Nevada Branch and coordinated with NTSO. Final engineering designs were developed by AEC contractors at NTS - Holmes & Narver, Inc. (H&N) and/or Fenix & Scisson, Inc. (F&S). Engineering drawings were approved by FCTC and NTSO prior to actual construction. Construction was performed by the principal AEC support contractor - REECo. FCTC and members of the test group staff monitored construction activities. The FC/DNA test group staff coordinated development of technical experiments and initiated action to obtain required support equipment (e.g., steel LOS pipe and mechanical closures). The test group staff reviewed the technical support requirements submitted by experimenter agencies and transmitted consolidated requirements to Nevada Branch which, in turn, advised the NTSO of future requirements.

During the construction phase, Nevada Branch began collecting containment-related information. During drilling or mining operations, rock cores were tested and analyzed for bulk density, moisture content, grain density, porosity (determined by the difference between bulk and grain densities), unconfined compressive strength, triaxial compression (for a variety of confining pressures), ultrasonic shear and compressive wave velocities, carbon dioxide content, presence of clay which could swell, and other features. Testing was done for DNA primarily by the H&N Testing Lab at NTS (Mercury) and TerraTek, a DNA contractor located at Salt Lake City, as part of the DNA containment research program.

As construction progressed, geologic features of the tunnels were examined and mapped, usually by an AEC contractor. Several months prior to planned event execution, FC/DNA prepared a document which contained a general description of the test, site geologic information, types and locations of mechanical closures, details of concrete plugs, summary of analytical calculations, and other related test history. This document was reviewed by Containment Evaluation Panel (CEP) members (see Section 2.1.3) and formally presented by FC/DNA to the CEP for categorization and recommendation for test execution.

The FC/DNA test group staff normally moved to NTS a few months prior to the planned event execution date (3 to 6 months depending upon the complexity of the test). Prior to arrival of DOD experimenter personnel, Nevada Branch made arrangements to provide required instrumentation and recording facilities, office space and equipment, communications equipment, vehicles, photography and other support items. Housing and food services for DOD personnel at NTS were provided by REECo. Upon arrival at NTS, DOD personnel were briefed on safety and security by the test group staff and other DOD and AEC personnel. Experimenter agencies were provided with copies of FC/DNA security and safety plans. These briefings included radiation safety control policies, procedures and equipment.

Under the supervision of the test group staff, experimenter personnel installed experiments and checked out instrumentation cables and recording systems. A series of electrical dry runs were conducted from the user laboratory control room and DNA monitor room at the Control Point complex to determine that all signals and remotely-controlled equipment were functioning properly. After all systems were declared ready, permission was requested from the AEC to install the nuclear device. Installation and check out were conducted by the participating device development laboratory with AEC security safeguarding the device and other classified materials. The next activities consisted of placing stemming materials in preplanned locations and checking all containment features.

When the test facility was ready for event execution, control of the entire test and experiment area was transferred to the AEC/NVOO Test Controller and his staff. When the Test Controller was satisfied that all conditions were satisfactory to execute the event, he gave permission to the user laboratory to arm the device and initiated the final countdown.

The Test Controller and his staff at the CP monitored the countdown, detonation, and postevent response of remotely-controlled monitoring equipment. When released by the Test Controller, REECo Radiological Safety (Radsafe) teams entered the area to monitor for radiation and other safety hazards. After assurance that reentry could be accomplished, the Test Controller released experimenters to collect recorded data from surface areas. All of these operations were conducted in accordance with plans developed pre-event by the AEC/NVOO Test Controller staff, the DOD test group staff, and Nevada Branch personnel, unless postevent conditions required modifications.

For tunnel events, initial reentry into the tunnel was authorized by the AEC Test Controller after he determined that conditions were safe for reentry operations. Tunnel reentry was controlled by Nevada Branch personnel with assistance from Sandia Laboratories, Albuquerque (SLA) health physicists, REECo Radsafe personnel, and REECo construction personnel. After the tunnel was declared safe for experiment recovery, the test group staff assumed control of the area. Based on REECo Radsafe monitoring data FC/DNA personnel determined when it was safe to remove tunnel experiments and data. Experimenters then removed experiments and data for analysis and documentation of results.

1.4 AEC ORGANIZATIONS, CONTRACTORS, AND RESPONSIBILITIES

1.4.1 Atomic Energy Commission

The AEC was created by the Atomic Energy Act of 1946 in July, the same month the Joint Chiefs of Staff were conducting Operation CROSSROADS with assistance from the U.S. Army's Manhattan Engineer District. MED was disestablished and the AEC and AFSWP assumed MED functions on 1 January 1947. The Atomic Energy Act was revised in 1954 and has been amended extensively since.

The AEC established headquarters (AEC/HQ) offices in Washington, D.C., and operations offices in areas which were centers of AEC operations. In areas of lesser activity, area offices, branch offices, and field offices were established. The Director of DMA in AEC/HQ was delegated responsibility for the nuclear weapons development and testing program. The Director of DMA always was a flag officer of one of the armed forces, as specified by the Atomic Energy Act of 1954, and he was an Assistant General Manager in the AEC organization.

In 1951, he designated and delegated his responsibility for conduct of on-continent tests to the Test Manager who also was Manager of the Santa Fe Operations Office (SFOO), near Los Alamos Scientific Laboratory (LASL). Later in 1951, SFOO was moved to Albuquerque. With delegated authority from the Director of DMA, the SFOO Manager designated Test Managers for on-continent tests. The same authority applied when SFOO became the Albuquerque Operations Office (ALOO) in 1956. The AEC Las Vegas Field Office (LVFO), established in 1951, managed the Nevada Test Site (called the Nevada Proving Ground from 1952 to 1955) for the Test Manager. LVFO became a branch office in 1955, an Area Office in 1960, and the Nevada Operations Office in 1962, with the NVOO Manager or his representative designated as Test Manager. In 1972, the Test Manager became the Test Controller.

1.4.2 Programmatic and Device Detonation Approvals

The Director of DMA (Division of Military Application was changed in 1977 to Office of Military Application) initiated the chain of authority and approval for detonating each nuclear device by requesting each user laboratory and DNA to submit proposed test programs to DMA. This request was made in the spring of each year for tests to be conducted in the next fiscal year. DMA consolidated proposed test programs, developed a test program proposal while consulting with DOD, and generated a program approval request. DMA then presented the proposed test program to the National Security Council (NSC) Ad Hoc Committee on Nuclear Testing. Chaired by the NSC, this Committee included representatives of DOD, Joint Chiefs of Staff, Department of State, Arms Control and Disarmament Agency, Office of Management and Budget, Office of Science and Technology, and Central Intelligence Agency. After incorporating informal Committee comments, DMA forwarded the proposed program from the Secretary of Energy to the President through the NSC. The NSC solicited and incorporated formal comments in its recommendation to the President.

Test program approvals were requested at six-month intervals. Approval of tests for the first six months was received at the beginning of each fiscal year. The process was repeated six months later for tests in the last half of the fiscal year. Presidential approvals were signed by the Assistant to the President for National Security Affairs. Subsequently, test program authority messages were sent from the Director of DMA to the user laboratories, DNA, and AEC/NVOO.

Authority to detonate each nuclear device was handled separately and individually. Technical content of detonation authority requests originated in presentations to the TEP by the user laboratory or DNA. After recommendations by the TEP, the AEC/NVOO Manager requested detonation authority from DMA. Required information in each request included statements on compliance with treaties, environmental impact, public announcement plans, test program authority, and any particularly noteworthy aspects of the test. After DMA and additional AEC reviews, the AEC/NVOO Manager was notified of detonation authority approval.

1.4.3 Nevada Test Site Organization

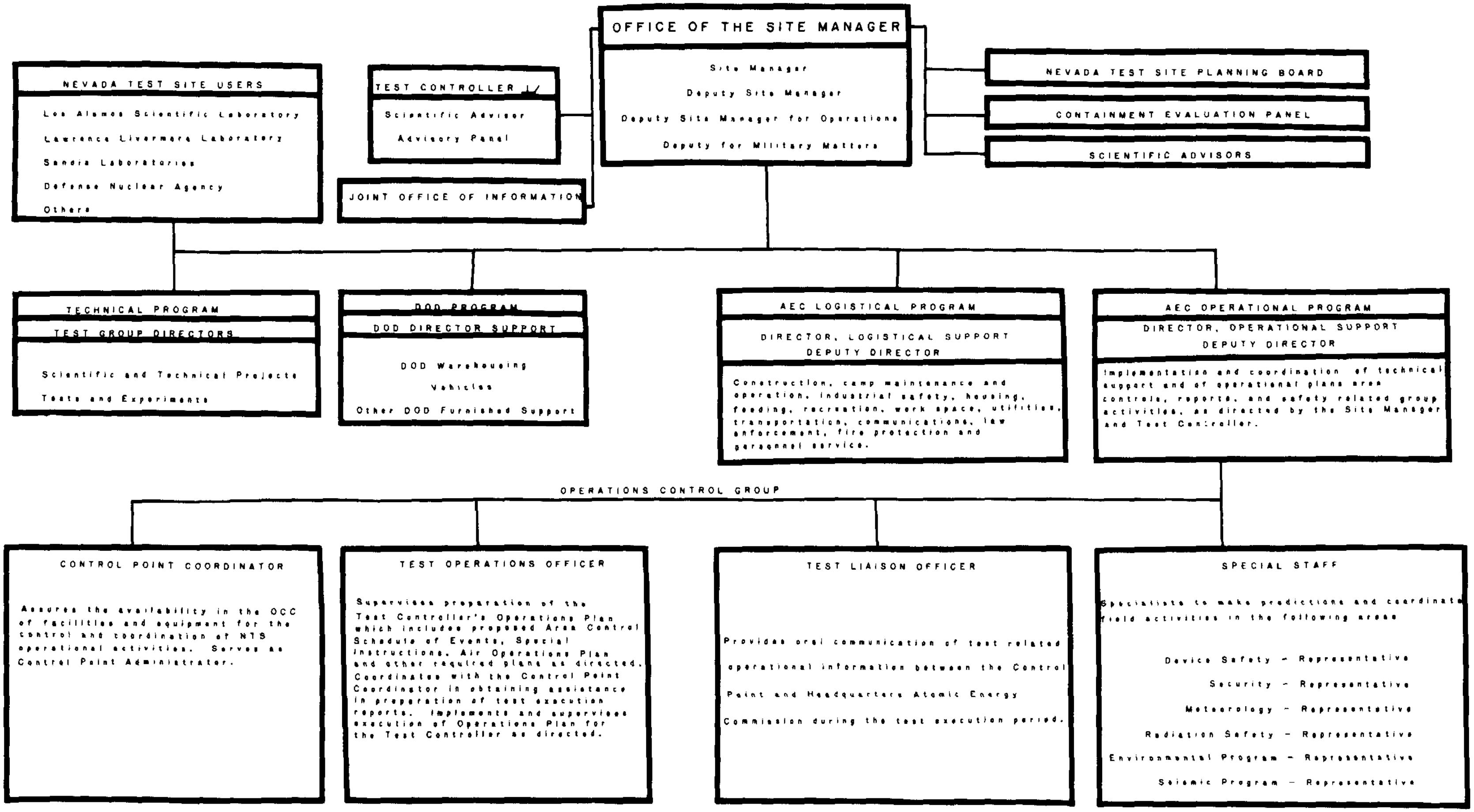
As stated in Chapter 0101 of the Nevada Test Site Organization Standard Operating Procedure NTSO-0101-01 (Appendix E), the NTSO included, AEC, DOD, other user laboratory and contractor personnel who participated in or provided support for test operations at the NTS. The Manager, AEC/NVOO, headed the NTSO (Figure 3). The NTSO was a continuing task organization whose composition could be readily changed in response to the needs and technical objectives of each test. The Continental Test Organization (CTO) was part of the original NTSO; however, it was disestablished on 1 August 1962 with its responsibilities (e.g., Military Deputy to the Manager, NVOO) being assumed by FC/DASA, WETG and subsequently by FC/DNA, Test Directorate. The Military Deputy to the Test Manager, as shown in Figure 3, was from Field Command and was responsible for coordinating DOD programs and support to NTSO.

1.4.4 NTSO Radiological Safety

The Test Controller was responsible for protection of participating personnel and offsite population from radiation hazards associated with activities conducted at NTS. By mutual agreement between the Test Controller and a scientific user (see Section 1.4.5), control of radiation safety within the area assigned for a particular activity was delegated to the user's Test Group Director during the period of time when such control could have had a direct bearing of the success or failure of the scientific program.

The onsite radiological safety support contractor (Radsafe) was responsible to the Test Controller for both routine and test event radiological safety onsite as detailed in Appendix D, USAEC NTSO SOP Chapter 0524, "Radiological Safety." During test events, as shown in Figure I of Appendix D and as discussed above, the Test Manager delegated control of radiation safety in the immediate test area to the user Test Group Director when he requested control. When this occurred, Radsafe was responsible to the Test Group Director through his radiological safety organization for support in his test area.

NEVADA TEST SITE ORGANIZATION



1/ Designated for each test or special experimental effort. Assumes operational control of NTS when directed by Manager, NV.

Figure 3. Nevada Test Site Organization (in 1972).

The U.S. Environmental Protection Agency (EPA)* was responsible to the Test Controller for operation of the offsite radiological safety program in accordance with procedures listed in Appendix D.

1.4.5 NTS Scientific Users

The NTS scientific users were DNA (for nuclear weapons effects) and the development laboratories: LASL, Lawrence Livermore Laboratory (LLL), and SLA. LASL and LLL were primarily involved in weapons related testing while SLA conducted a limited number of weapons effects tests and supported weapons related tests. A brief description of these laboratories follows:

A. LASL was established early in 1943 as Los Alamos, Project Y, of the MED for the specific purpose of developing an atomic bomb. Los Alamos scientists supervised the test detonation of the world's first atomic weapon in July 1945 at the TRINITY site in New Mexico. Los Alamos became LASL in January 1947, when the AEC and AFSWP were activated to replace the MED. The Laboratory's continuing assignment was to conceive, design, test, and develop nuclear components of atomic weapons. The contract under which LASL performed work for the AEC was first administered by the AEC Santa Fe Operations Office and later by the AEC Albuquerque Operations Office. The Laboratory was operated by the University of California.

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*The U.S. EPA was established in 1971, and the Las Vegas, Nevada office of the U.S. Public Health Service (USPHS) became a part of the EPA.

B. LLL (originally UCRL and then Lawrence Radiation Laboratory) was established as a second AEC weapons laboratory at Livermore, California, in 1952. The Laboratory's responsibilities essentially were parallel to those of LASL. Devices developed by LLL first were tested in Nevada in 1953, and LLL-developed devices have been tested in each continental and Pacific series since. The contract under which LLL performed work for the AEC was administered by the AEC San Francisco Operations Office. This Laboratory also was operated by the University of California.

C. SLA (originally Sandia Laboratory) at Sandia Base (now KAFB), Albuquerque, New Mexico, was the AEC's other weapons laboratory. It was established in 1946 as a branch of Los Alamos, but in 1949 assumed its identity as a full-fledged weapons research institution operated by the Sandia Corporation, a non-profit subsidiary of Western Electric. SLA's role was to conceive, design, test, and develop the non-nuclear phases of atomic weapons and to do other work in related fields. In 1956, a Livermore Branch of Sandia Laboratories (SL) was established to provide closer support to developmental work of LLL. SL also operated ballistic test facilities for the AEC at the Tonopah Ballistics Range (now Tonopah Test Range) near Tonopah, Nevada.

1.4.6 Test Support Organizations

In keeping with its policy, AEC used private contractors for maintenance, operations, and construction (including military and civil defense construction) at the NTS. AEC/NVOO personnel administered all housekeeping, construction, and related services activity, but performance was by contractors. Major support contractors were the following:

Reynolds Electrical & Engineering Company, Inc., was the principal AEC operational and support contractor for the NTS, providing electrical and architectural engineering, state-of-the-art large diameter and conventional shaft drilling, heavy duty construction and excavation, mining and tunneling, occupational safety and fire protection, radiological safety, toxic gas and explosive mixture monitoring, communications and electronics, power distribution, occupational medicine, and other support functions. REECo maintained offices in Las Vegas and extensive facilities necessary to operate NTS.

Edgerton, Germeshausen & Grier, Inc., of Boston, Massachusetts, was the principal technical contractor, providing control point functions, such as timing and firing, and diagnostic functions, such as scientific photography and measurement of detonation characteristics. In addition, EG&G personnel manned the DOD monitor room. EG&G support facilities were maintained in Las Vegas and at NTS.

Holmes & Narver, Inc., performed architect-engineer services for the NTS and was the principal support contractor for AEC off-continent operations. H&N had a home office in the Los Angeles area and also maintained offices in Las Vegas and at NTS.

Since 1963, Fenix & Scisson, Inc., Tulsa, Oklahoma, was a consultant architect-engineer for drilling and mining operations in connection with underground nuclear testing. The company was involved in design of many underground structures, and in the field of deep, large-diameter, hole drilling. Las Vegas Branch activity was conducted from offices in Las Vegas and Mercury, Nevada.

Numerous other contractors, selected on the basis of lump-sum competitive bids, performed various construction and other support functions for AEC and DOD.

1.5 THE NEVADA TEST SITE

An on-continent location was selected for conducting nuclear weapons tests; construction began at what was called the Nevada Test Site in December 1950, and testing began in January 1951. The name was changed to the Nevada Proving Ground (NPG) in March of 1952 and again changed to the Nevada Test Site in 1955.

The original boundaries were expanded as new testing areas and projects were added. Figure 4 shows the present NTS location bounded on three sides by the Nellis Air Force Range. The area of NTS was about 1,350 square miles in 1987. This testing location was selected for both safety and security reasons. The arid climate, lack of industrialization, and exclusion of the public from the Nellis Air Force Range combined to result in a very low population density in the area around NTS.

The only paved roads within the NTS and Nellis Air Force Range complex were those constructed by the government for access purposes. NTS testing areas were physically protected by surrounding rugged topography. The few mountain passes and dry washes where four-wheel drive vehicles might enter were posted with warning signs and barricades. NTS security force personnel patrolled perimeter and barricade areas in aircraft and vehicles. Thus, unauthorized entry to NTS was difficult, and the possibility of a member of the public inadvertently entering an NTS testing area was extremely remote.

Figure 5 shows the NTS, its various area designations, and the locations of the seven test events covered by this volume.

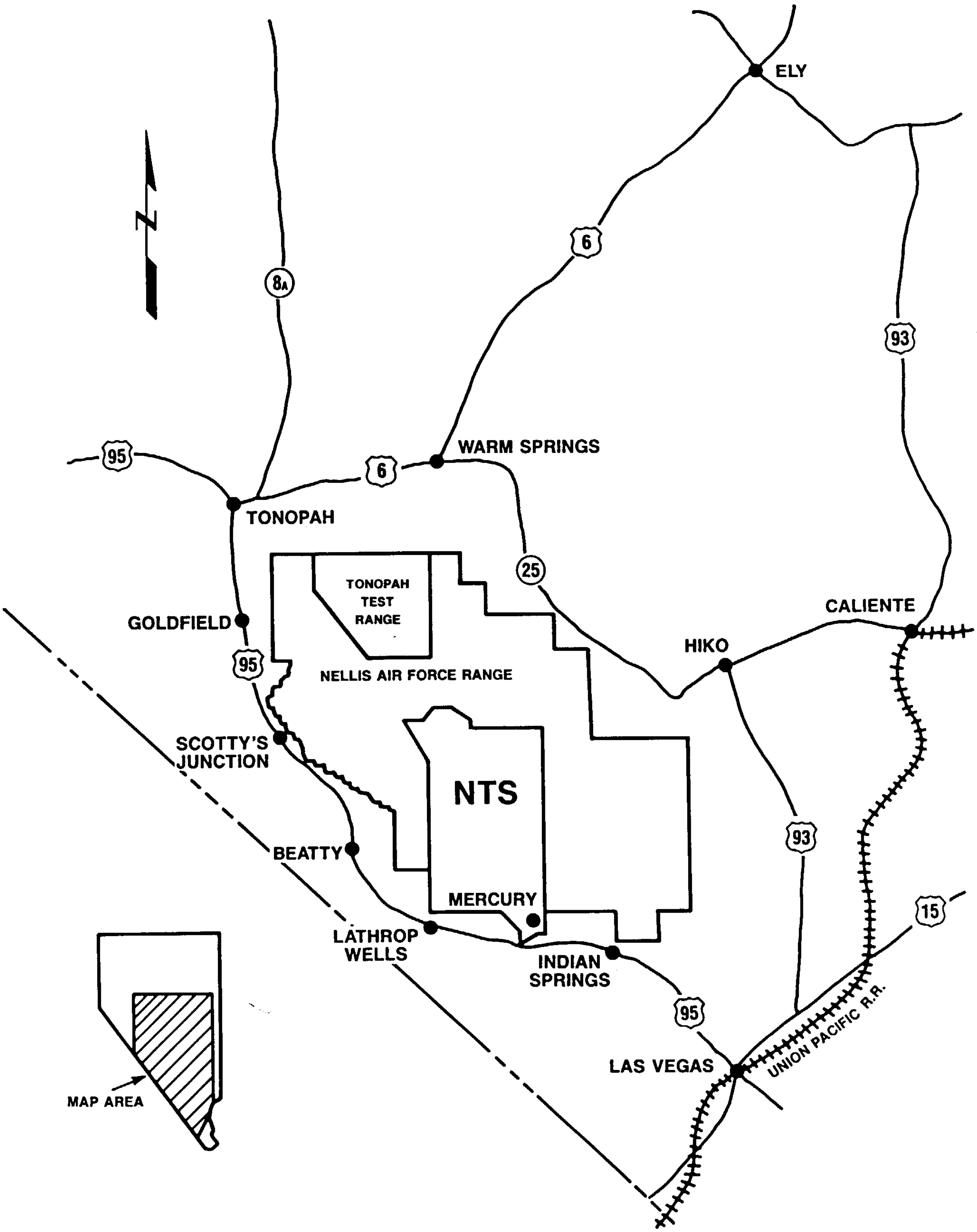

Figure 4. Nellis Air Force Range and NTS in Nevada (in 1972).

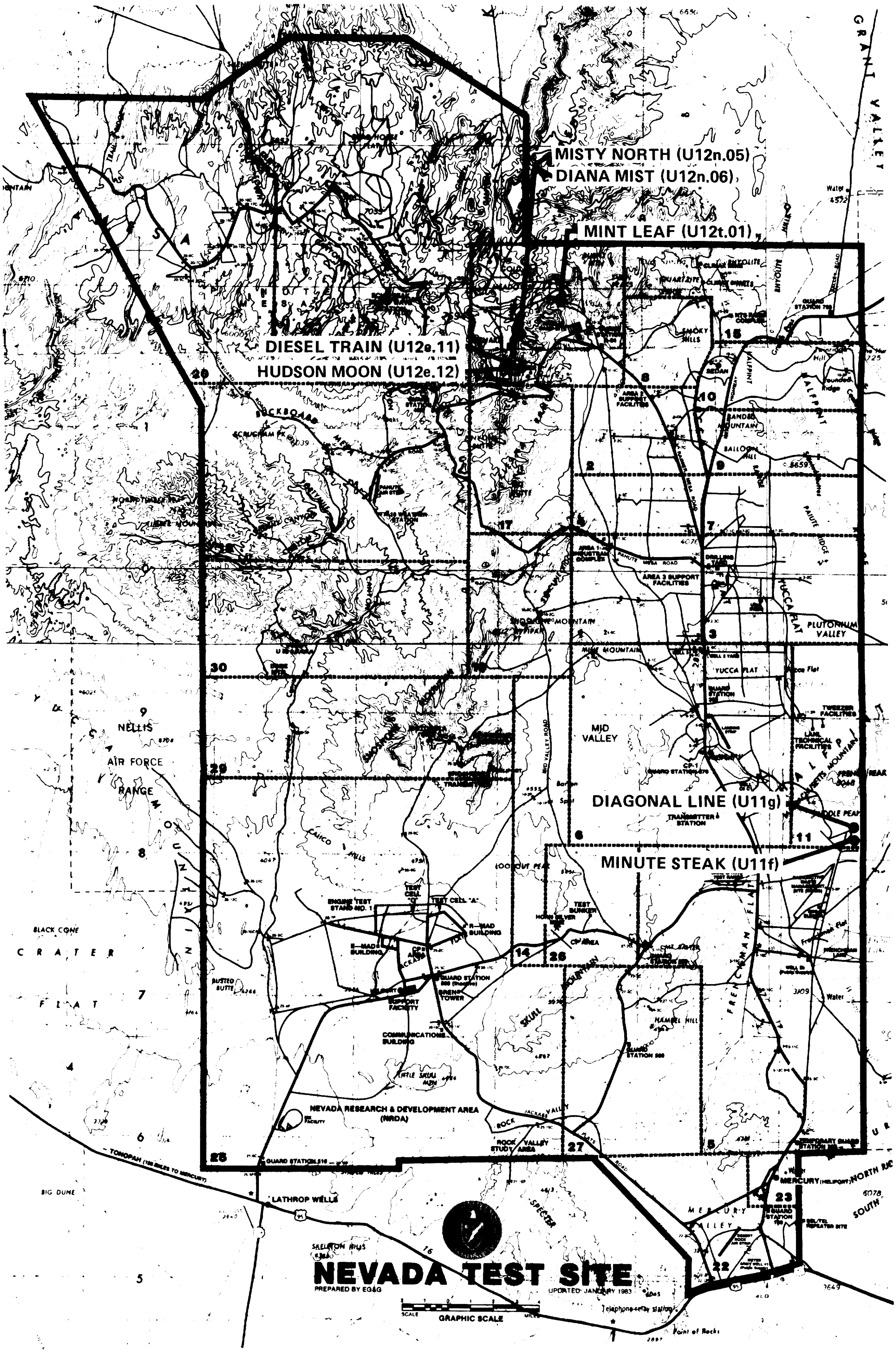

Figure 5. The Nevada Test Site.

Generally, the "U" means an underground location, the number the area, and the "a" the first test location in an area; in addition, for tunnels, the "t.01" indicates the first drift from the main "t" tunnel, as U12t.01 in Figure 5.

A low mountain range separated the base camp, Mercury, from the location of early AEC and DOD atmospheric tests at Frenchman Flat in Area 5. This area was later used for DOD underground testing. The elevation of Frenchman Dry Lake in the middle of the Flat is about 3,100 feet.

A mountain pass separates Frenchman Flat from Yucca Flat testing areas. The pass overlooks both Frenchman and Yucca Flats and contains the CP complex of buildings including Control Point Building 1 (CP-1) where timing and firing for most atmospheric tests was performed, and Control Point Building 2 (CP-2) where radiological safety support was based.

Yucca Flat testing areas include Areas 1, 2, 3, 4, 7, 8, 9, and 10. Underground tests were conducted in most of these areas and generally were shaft emplacement types. The elevation of Yucca Dry Lake at the south end of Yucca Flat is about 4,300 feet. To the west of Yucca Flat, in another basin, is the Area 18 testing location. Some DOD atmospheric tests were conducted in Area 18, and one DOD cratering event, DANNY BOY, was conducted on Buckboard Mesa in this area at an elevation of about 5,500 feet. Area 16 is in the mountains west of Yucca Flat toward Area 18. The single Area 16 tunnel complex at an elevation of about 5,400 feet was a DOD underground testing location.

Rainier Mesa is in Area 12 northwest of Yucca Flat, and the top of the Mesa is at an elevation of about 7,500 feet. All DOD tunnel-emplacement type events on NTS that were not in the Area 16 tunnel complex or the Area 15 shaft and tunnel complex were in Rainier Mesa and the adjoining Pahute Mesa (parts of T Tunnel were constructed in the adjoining Pahute Mesa). The major Rainier Mesa tunnel complexes were B, E, G, N, and T tunnels.

Area 15 is in the foothills at the north end of Yucca Flat. The deepest of two access shafts drops 1,500 feet below the surface elevation of 5,100 feet. There were three events conducted in Area 15, all sponsored by DOD. HARD HAT and TINY TOT were discussed in Report DNA 6320F, Operations NOUGAT and WHETSTONE while PILE DRIVER was discussed Report DNA 6321F, Operations FLINTLOCK and LATCHKEY.

CHAPTER 2

UNDERGROUND TESTING PROCEDURES

Underground tests conducted at the NTS prior to 1962 primarily were weapons related or were safety tests. These tests were controlled by the AEC and conducted by LASL or UCRL. Experience gained during these tests, in the area of containment of radioactivity underground, provided basic concepts to aid development of containment plans for DOD/DNA sponsored underground nuclear weapons effects tests which followed. These DOD tests generally were more complex than earlier AEC tests and required the development of new containment concepts and hardware.

A primary consideration in all underground tests was the safety of test participants and the general public, especially regarding exposure to radioactive materials. This chapter discusses, in general terms, the basic mechanics of underground testing, containment and procedures, types of emplacement, diagnostic techniques, area access requirements, industrial and radiological safety, and radiation measuring systems.

2.1 CONTAINMENT, PROBLEMS, AND PROCEDURES

Completely containing radioactive material underground while accomplishing diagnostic measurements and effects experiments proved to be a major engineering challenge. Original efforts considered only detonation containment in competent rock formations. It was necessary to modify the original efforts to consider zones of weakness in rock caused by faults, and containment failures resulting from diagnostic and experiment structures. Under certain conditions, particularly the presence of clay or higher water content in rock near the detonation point, greater than normal stresses could be generated, which could adversely affect containment. Some containment failures were partially attributable to additional overpressure from secondary gas expansion or, in other words, steam pressure. The major containment features and problems that evolved are discussed below.

2.1.1 Shaft Event Containment

Some of the first shaft-type safety experiments were in unstemmed shafts with concrete plugs penetrated by cable and instrumentation holes. When nuclear yields were produced, these emplacements did not completely contain the radioactive debris. The first method used to fully contain nuclear detonations in shafts was stemming, or filling the shaft with aggregate and sand after device emplacement.

Keyed concrete plugs at different depths in the shaft stemming sometimes were used. The shaft diameter was enlarged at the plug construction location so the poured concrete plug would key into the ground surrounding the shaft and provide more strength against containment failure. Combinations of concrete and epoxy were used later, and epoxy replaced concrete as a plug material for some shaft-type emplacements.

Radiochemical sampling pipes, LOS pipes, and other openings in stemming and plug containment features had to be closed rapidly after the detonation to prevent venting of radioactive effluent to the atmosphere. Closure systems driven by high explosives or compressed air were developed to seal the openings. After some of these early systems did not prevent releases of effluent to the atmosphere, use of openings to the surface for diagnostic or experiment purposes was discontinued for several years until technology improved.

Scientific and other cables from the device emplacement to the surface were another source of containment problems. While cables could be embedded in concrete and epoxy, which helped prevent leakage along the outside of the cables, radioactive gases under high pressure traveled along the inside of cables as a conduit to the surface. This problem was solved by embedding the inner components of cables in epoxy at appropriate locations or intervals, such as in epoxy or concrete plugs, in a technique called gas blocking.

The most serious containment problems were caused by unanticipated geologic and hydrologic conditions at particular test locations. Even careful and rigorous calculations, engineering, construction, and preparations were inadequate when the presence of a geologic zone of weakness near the detonation point toward the surface was unknown.

Another similar problem was the presence of higher water content than anticipated in rock formations surrounding or near the detonation point. This problem caused greater shock transmission plus secondary gas expansion when the water turned to steam. In addition, presence of sufficient iron in the test configuration caused disassociation of water with subsequent greater secondary gas expansion from hydrogen gas. A result was much higher and longer-sustained pressure from the detonation point toward the surface, and possible subsequent failure of geologic or constructed containment mechanisms.

Recognizing and understanding geologic and hydrologic conditions at each test location was necessary before these containment problems could be solved. As additional information became available through drilling and intensive geologic studies, these problems were lessened by investigations of proposed detonation locations and application of detailed site selection criteria.

2.1.2 Tunnel Event Containment

As with shaft-type detonations, containment methods used for tunnel events were designed using basic characteristics of the nuclear detonation. Tunnel configurations were constructed with device emplacements strategically located to cause sealing of the access tunnel by force of the detonation. Additional containment features were used to contain radioactive debris.

One of the original user laboratory stemming configurations consisted of one or more sandbag plugs installed a short distance from the projected self-sealing location toward the tunnel entrance (portal). Two plugs, each about 60 feet in length, were a typical installation. The sandbag plugs later were changed to solid sand backfill plugs several hundreds of feet long from the device location. In many cases, the sand stemming had short sections of air voids between the plugs. Farther toward the portal, a keyed concrete plug with a metal blast door was constructed. The blast door was designed to contain any gases, with pressures up to 75 pounds per square inch (psi), that might penetrate the sandbag plugs.

Also as with shaft-type detonations, the unknown presence of undesirable geologic and hydrologic conditions sometimes caused venting of radioactive effluent either through the overburden (ground above the tunnel) to the surface, through fissures opened between the detonation point and the main tunnel, or through the plugs and blast door to the main tunnel vent holes and portal. More substantial containment features evolved as containment problems became better understood and tunnel events became more complex.

The first DOD tunnel test was MARSHMALLOW (1962). Stemming for that event consisted of four sandbag plugs extending out to a distance of a few hundred feet from the nuclear device (similar to earlier AEC-sponsored events). A gas seal door (blast door) was installed in the main access drift. The next DOD tunnel test (GUMDROP, 1965) used sand backfill, with a few air gaps, out to a few hundred feet. As DOD tunnel testing continued, sand plugs gradually were replaced with various grout mixtures. Some grout mixtures were designed to match the strength and shock propagation of the native tunnel material (usually ash-fall tuff) while other grout mixtures were designed to be weaker and to form a solid stemming plug shortly after device detonation.

Also, as tunnel testing continued, the gas seal (blast) door no longer was used as a containment device and was replaced by strong concrete plugs 10 to 20 feet long. These plugs were keyed into the tunnel wall and were designed to withstand overpressures up to 1000 psi. A small access hatch was constructed, and some of the plugs were penetrated with electrical cables and steel pipes. All of these penetrations were gas sealed, or capped, to provide protection against possible gas seepage through the plug.

Use of horizontal line-of-sight (HLOS) pipes in tunnel events necessitated development of additional closure systems. The HLOS pipe tunnel and its access tunnels generally were separated from the main tunnel by one or more concrete plugs. These closure systems primarily were for protection of the experiments inside the HLOS pipe but also were considered useful features for the formation of a stemming plug.

The tunnel volume outside of the pipe was filled by stemming or grouting, while the experiments inside the HLOS pipe were protected by mechanical closure systems. Various closure systems were used, including compressed air or explosive-driven gates and doors which closed off the HLOS pipe from the detonation within a small fraction of a second after detonation time. One of these mechanical closures was the tunnel and pipe seal (TAPS) unit, first used on the DOOR MIST event. The TAPS was a heavy steel door that was released at shot time and fell to the closed position in less than one second.

Gas blocking techniques similar to those used in shaft events were used to prevent leakage of radioactive gases along or through cables from the diagnostic and experiment locations to the surface. Additionally, a gas seal door usually was installed in the main drift nearer the portal than the concrete plug. Utility pipes, such as for compressed air, that passed through stemming and plugs also were sealed by closure systems.

2.1.3 Containment Evaluation Panel

When containment problems were particularly difficult, the AEC began to change its emphasis on conditions under which nuclear detonations should be conducted.

The Manager, AEC/NVOO, had primary responsibility for taking all reasonable steps to assure that each test was successfully contained and carried out in accordance with AEC policies. Containment of DOD tests was a joint effort on the part of AEC, DOD, and contractor scientists and engineers. To carry out this responsibility, AEC/NVOO established a Test Evaluation Panel (TEP) on 17 December 1963 to review plans presented by user testing organizations (LASL, LLL, SL, and FC/DNA) for each test program. The chairman of this panel represented the Manager, AEC/NVOO and membership consisted of two representatives (one voting member plus an alternate) from each of the user testing organizations, plus specialists from contractor and other government organizations (such as the U.S. Geological Survey). Other AEC/NVOO contractor personnel were available to present information in their areas of expertise (e.g., mining and drilling operations). The primary concern of this panel was the underground containment of radioactive material.

On 19 March 1971 while testing was suspended because containment failure had caused serious venting of a laboratory test (BANEBERRY Event), the TEP was changed to the Containment Evaluation Panel (CEP). The CEP was instructed to give increased emphasis to containment of radioactive material and the membership of the panel was enlarged to include contractors and consultants representing additional areas of expertise. Each underground testing organization was represented as before.

Prior to a formal meeting of the CEP, each user planning a nuclear test prepared a written containment prospectus which was submitted to each panel member for review. This information was then presented to the CEP by the individual users, generally at the next meeting (meetings were held about ten times a year). Details of the containment plan and comparisons to previous successful experiences were reviewed by the panel. Each member (or alternate) was requested to submit a written statement describing the details considered favorable or unfavorable to successful containment and to vote a Category A, Category B, or Category C.

Successful containment was defined as containment such that a test resulted in no radioactivity detectable offsite as measured by normal monitoring equipment and no unanticipated release of radioactivity onsite. Anticipated releases were designed to conform to specific guidance from AEC/DMA. Category A was defined as "considering all containment features and appropriate historical, empirical, and analytical data, the judgment of the member indicates a high confidence in successful containment." Category B was defined as "considering all containment features and appropriate historical, empirical, and analytical data, the best judgment of the member indicates a lesser, but still adequate, degree of confidence in successful containment." Category C was defined as "considering all containment features and appropriate historical, empirical, and analytical data, the best judgment of the member indicates some doubt that successful containment will be achieved." A written report of the CEP meeting, containing the containment prospectus, the record of all discussion and the vote of each member or independent consultant, was forwarded to Headquarters, AEC, for review and recommendation for approval to execute the event.

2.1.4 Test Manager's Advisory Panel

Careful consideration of each test event by the CEP to avoid releases of radioactive effluent to the atmosphere was followed by additional precautions prior to test event execution. If an unanticipated release of effluent from an underground detonation occurred, it was necessary to assure protection of onsite participants and the offsite population. The Test Manager's Advisory Panel was composed of a Scientific Advisor and representatives from each organization which could contribute information to this protection goal.

This Panel met at readiness briefings in advance of each event and in the Control Room prior to and during execution of each event. Panel members briefed the Test Manager's representative, later named the Test Controller (who replaced the Test Manager in 1972), on aspects of containment, seismic shock, possible radiation releases, weather, and area control plans pertinent to that particular test. Information presented was then evaluated by each Advisory Panel member and a recommendation to proceed with the test or to delay for more favorable conditions was made.

Meteorological conditions were considered in detail. National weather data were coupled with local wind data (obtained from weather balloons released and tracked from stations on and around NTS) both preceeding and during each test to predict where an unanticipated release of effluent might be transported off NTS and what the levels of radiation might be in the predicted effluent cloud directions. These meteorological data also were used with appropriate release models to calculate potential external gamma exposures and thyroid doses at offsite locations.

Locations of population centers, each dairy cow, and people at ranches and mines in the projected effluent cloud directions were presented and evaluated. EPA personnel in the offsite areas notified mining people to be above ground for safety purposes at the anticipated detonation time of tests which might cause a ground shock hazard. This information and numbers of people who might need to be advised to stay under cover or be evacuated were presented for consideration. EPA personnel started offsite air samplers and placed radiation dosimeters in offsite locations before detonation time. Readiness information included capability for advising state officials to institute a milk diversion program if cattle feed or milk might become contaminated, and to replace milk and dry feed for family dairy cows.

Status of standby aircraft for effluent cloud sampling and tracking capability was presented. Communications between offsite weather stations and EPA personnel were checked to assure proper operation.

Radsafe personnel onsite assured that remote radiation monitoring stations in the test area and in other NTS areas were functional. Data from these stations, the weather stations, offsite EPA personnel, and personnel clearing the test area were displayed in the Control Room for continued visual examination by the Test Controller and the Advisory Panel. In addition, closed-circuit television cameras were operational in the test area on the ground and in helicopters to detect any visual indications of possible effluent release and alert the Test Controller and the Advisory Panel members.

If the Test Controller decided that a projected effluent direction was close to populated areas, or weather conditions were not stable enough to determine the direction of any released effluent after detonation, the decision was not given to arm and detonate and the test was either postponed for another day or placed on hold until conditions were favorable.

Conditions were considered favorable when projected effluent direction was toward sparsely populated areas, weather conditions were relatively stable, EPA personnel could contact the few residents in the projected effluent direction and advise them of protective actions to be taken, and impact on milk supply from dairy cattle would be minimal. In addition, all essential equipment, personnel, and procedures were required to be in readiness status or initiated before permission to arm and detonate was given.

Permission to arm usually was given at least two hours before detonation to allow time for arming, securing of the test configuration and containment systems, and departure of the arming party from the test area. The detonation, however, could be delayed at any moment up to detonation time, or postponed until another day when conditions were favorable.

The Test Controller and the Advisory Panel received information, watched visible displays, and communicated with their field personnel up to detonation and after the test for a sufficient time to assure that venting had not occurred. Remote radiation detection instrument readings and closed-circuit television of the test area were monitored to detect any indication of effluent release.

When all other indications of venting were negative, and the Test Controller determined personnel could reenter the test location, (e.g., subsidence craters had formed for shaft-type detonations, and cavity collapse had occurred for tunnel-type emplacements, as indicated by geophones) initial radiation survey teams entered the test area to confirm that radioactive effluent had not been released and that any radiation levels were low enough for experiment data recovery to begin. For tunnel emplacement-type tests, reentry of the tunnel itself, after initial survey of the surface areas and recovery of data, was a matter for separate and careful consideration by the Test Group Director and radiological safety personnel.

2.1.5 Effluent Release Procedures

If radioactive effluent was released from an underground test event, established procedures were initiated in accordance with the intent of NTSO-0524, "Radiological Safety (Appendix D): protection of participating personnel and off-site population from radiation hazards associated with activities conducted at the NTS." Immediately upon detection of possible venting and effluent release after a detonation, the following procedures were to be initiated:

A. For some tests, Radsafe survey teams were at manned stations in the test area. These teams or those at check points were released to make radiation measurements to be used in determining direction and radiation levels of radioactive effluent.

B. Aircraft were standing by to sample and track the effluent. Data reported were used to further refine information on effluent direction and radioactivity concentrations.

C. EPA monitors in offsite areas, previously stationed in the projected path of any released effluent, were advised of actual effluent direction and radioactivity measurement data and directed to move sampling and dosimeter equipment, perform ground radiation surveys, and notify residents and workers in the effluent path of any necessary precautionary measures, such as remaining in buildings or evacuating the area temporarily.

D. Capabilities were held in readiness to advise state officials to implement a milk diversion program. If this was necessary, Nevada and neighboring state officials could be advised to impound and replace milk supplies possibly contaminated through the cattle feed pathway, and hold impounded milk for decay of the probable contaminants, radioiodines, before using it for other purposes. On a localized basis, EPA personnel were ready to replace family dairy cow milk with fresh milk, and analyze milk for concentrations of specific radionuclides. Dry feed supplies also could be replaced for family dairy cattle if required.

E. Capabilities were in readiness for thyroid monitoring of offsite individuals possibly exposed to radioiodines in the effluent. These mobile monitoring stations could be used in the offsite areas for screening measurements to determine if any offsite residents or workers exhibited thyroid radioactivity and should be transported to Las Vegas facilities for more precise thyroid measurements and dose assignment.

Each of the above procedures was established to avoid or minimize exposure of the offsite population and maintain any such exposures below the radiation protection standards for individuals and population groups in uncontrolled areas, as established in NTSO-0524, "Radiological Safety" (see Appendix D).

While the above procedures were to be initiated, additional onsite procedures were to be implemented. Radsafe survey teams, when released by the Test Controller, were to survey the test area in sufficient detail to plot gamma radiation isointensity lines on NTS maps and provide specific intensity measurements at experiment stations on the surface and at other locations of interest. These data could be used by the Test Controller in releasing personnel to enter radiation areas in the controlled area, and by the Test Group Director in determining when surveys of his immediate test area and recoveries of experiment data could be accomplished. These decisions included calculations of personnel gamma radiation doses based on survey data, radiation intensities at recovery locations, and estimated times in area, and assurance that exposures would be limited only to those necessary and below the standards established in NTSO-0524.

Some tunnel-type emplacement tests that did not result in venting of radioactive effluent to the atmosphere did result in failure of containment systems within the tunnels. High radiation levels then existed in locations where reentry personnel needed to enter for data recovery purposes. Procedures developed to minimize exposures of reentry and recovery personnel included remote radiation detectors located at strategic tunnel complex locations, remote tunnel atmosphere samplers that removed tunnel air to locations outside the tunnel for analysis, and tunnel filtration systems that allowed controlled ventilation of tunnels before reentry, with only gaseous radionuclides released to the atmosphere.

The remote monitoring and sampling equipment provided information on radiation levels, toxic gases, and explosive mixtures necessary to determine whether tunnel ventilation should be accomplished before reentry. Tunnel filtration systems stopped particulate radioactivity, and activated charcoal in the filter system absorbed most of the radioiodines, thus allowing primarily only radionuclides of the noble gases, such as xenon, to be released to the atmosphere. Exposure to radionuclides of the noble gases is far less hazardous than exposure to the other fission products. Release of this radioactive material to the atmosphere in a gradual, controlled manner during tunnel ventilation always was subject to approval by the Test Controller.

2.2 EMPLACEMENT TYPES

The DOD conducted seven underground nuclear tests which are covered in this report period, and two VELA UNIFORM tests which are not covered (see Preface) during this report period. Table 1 lists the seven events and pertinent data. There were two shaft and five tunnel-type tests during Operations MANDREL and GROMMET. These emplacement types are discussed in this section. An emplacement type not discussed in this volume is one that results in excavating or ejecting material from the ground surface to form a crater (see Crater Experiment in the Glossary of Terms). A DOD cratering event, DANNY BOY, was conducted in 1962 during Operation NOUGAT.

2.2.1 Vertical Shaft-Type Emplacement

A shaft-type nuclear detonation was intended to be contained underground. A vertical shaft was usually drilled, but sometimes mined, and it may have been lined with a steel casing or have been uncased. The nuclear device was emplaced at a depth established to contain the explosion. At detonation time, a cavity formed by vaporized rock under pressure held surrounding broken rock in place until the cavity cooled sufficiently to decrease pressure. As broken rock fell into the cavity formed by the detonation, a chimney was formed. If the chimney of falling rock reached the surface, a subsidence crater was formed. Figure 6 shows a typical subsidence crater.

Table 1. DOD Events - 12 September 1969 thru 2 May 1972.

OPERATION	MANDREL					GROMMET	
TEST EVENT	MINUTE STEAK	DIESEL TRAIN	DIANA MIST	MINT LEAF	HUDSON MOON	DIAGONAL LINE	MISTY NORTH
DATE	12 Sep 69	5 Dec 69	11 Feb 70	5 May 70	26 May 70	24 Nov 71	2 May 72
LOCAL TIME (hours)	1102 PDT	0900 PST	1115 PST	0830 PDT	0716 PDT	1215 PST	1215 PDT
NTS LOCATION	U11f	U12e.11	U12n.06	U12t.01	U12e.12	U11g	U12n.05
TYPE	Shaft	Tunnel	Tunnel	Tunnel	Tunnel	Shaft	Tunnel
DEPTH (feet)	867	1,386	1,319	1,330	1,386	867	1,234
YIELD*	Low	Low	Low	Low	Low	Low	Low

* LOW INDICATES LESS THAN 20 KILOTONS

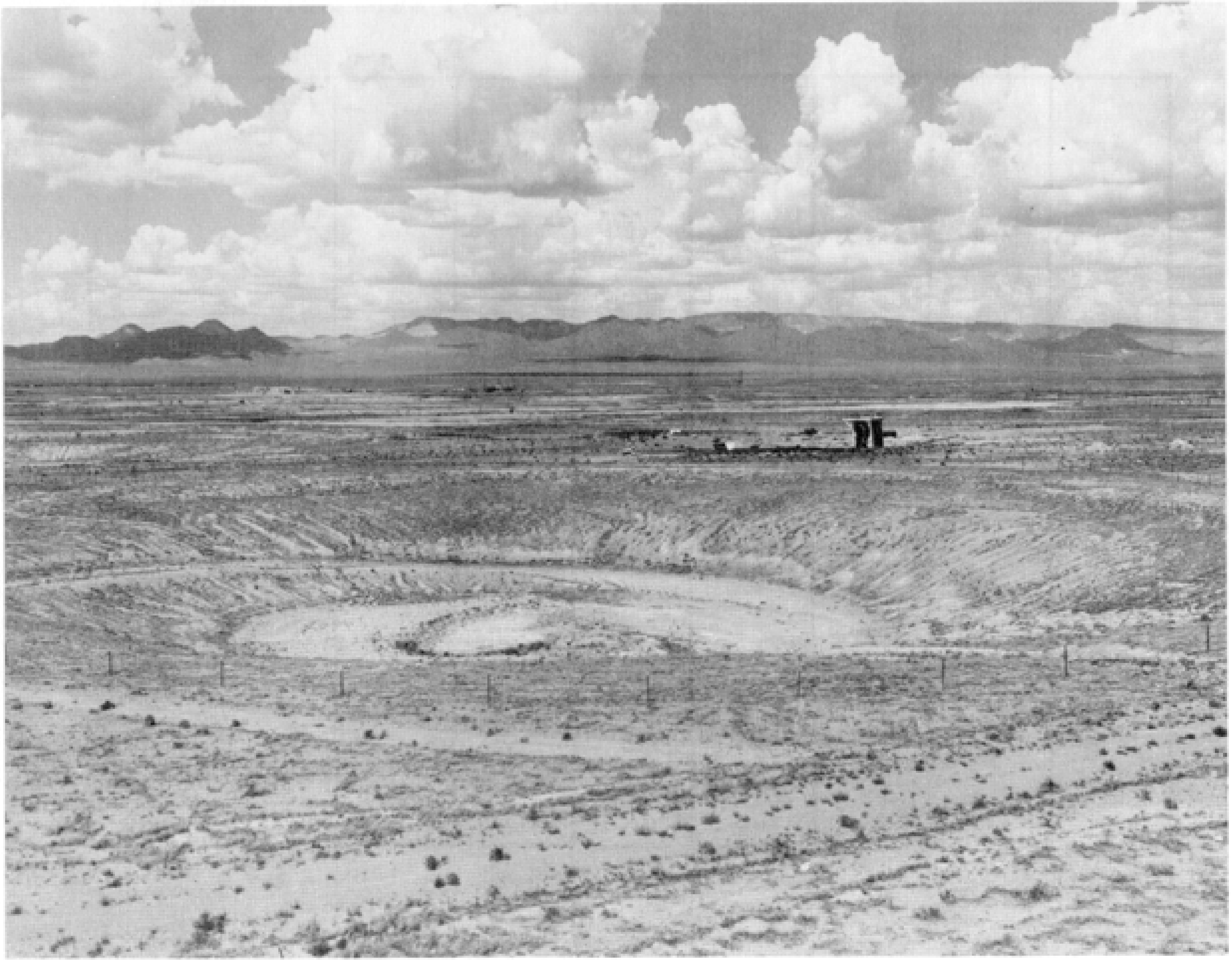

Figure 6. A typical subsidence crater.

If a device was emplaced too deeply in the alluvium of Frenchman or Yucca Flat for the detonation yield, or the depth was correct but the yield was much less than anticipated, a subsidence crater might not form; that is, the chimney might not reach the surface. This was a problem during early years of underground testing when it was necessary to move drill rigs into subsidence craters soon after tests for cavity sample recovery purposes. If a subsidence crater did not form, drill rigs could not be moved to surface ground zero (SGZ). When directional drilling from outside the crater was implemented, lack of a subsidence crater in alluvium became less of a problem. Experience gained with depth of device burial also reduced the chance of subsidence craters not forming in alluvium.

The two vertical shaft-type underground tests conducted by DOD during the period covered by this volume each included a vertical line-of-sight (VLOS) pipe system to the surface and a mobile tower on the surface that contained the weapons effects experiments (see Figure 7). The VLOS pipe system contained several mechanical closures designed to prevent the release of radioactivity into the atmosphere. These closures were open at the time of detonation but closed within milliseconds to stop the flow of material up the pipe. The open volume between the VLOS pipe and the wall of the drill hole was filled with sand and other materials. One or more non-porous material plugs were placed around the pipe. Electrical cables which went downhole were gas blocked to prevent gas seepage to the surface. Effects experiments were contained in a mobile tower on the surface that was moved away from the hole after device detonation, but before surface collapse (formation of subsidence crater). One potential problem was the possibility of seepage after surface collapse if some pathway to the surface developed. Some radioactive effluent was released into the atmosphere after several previous VLOS-pipe system tests not covered in this report.

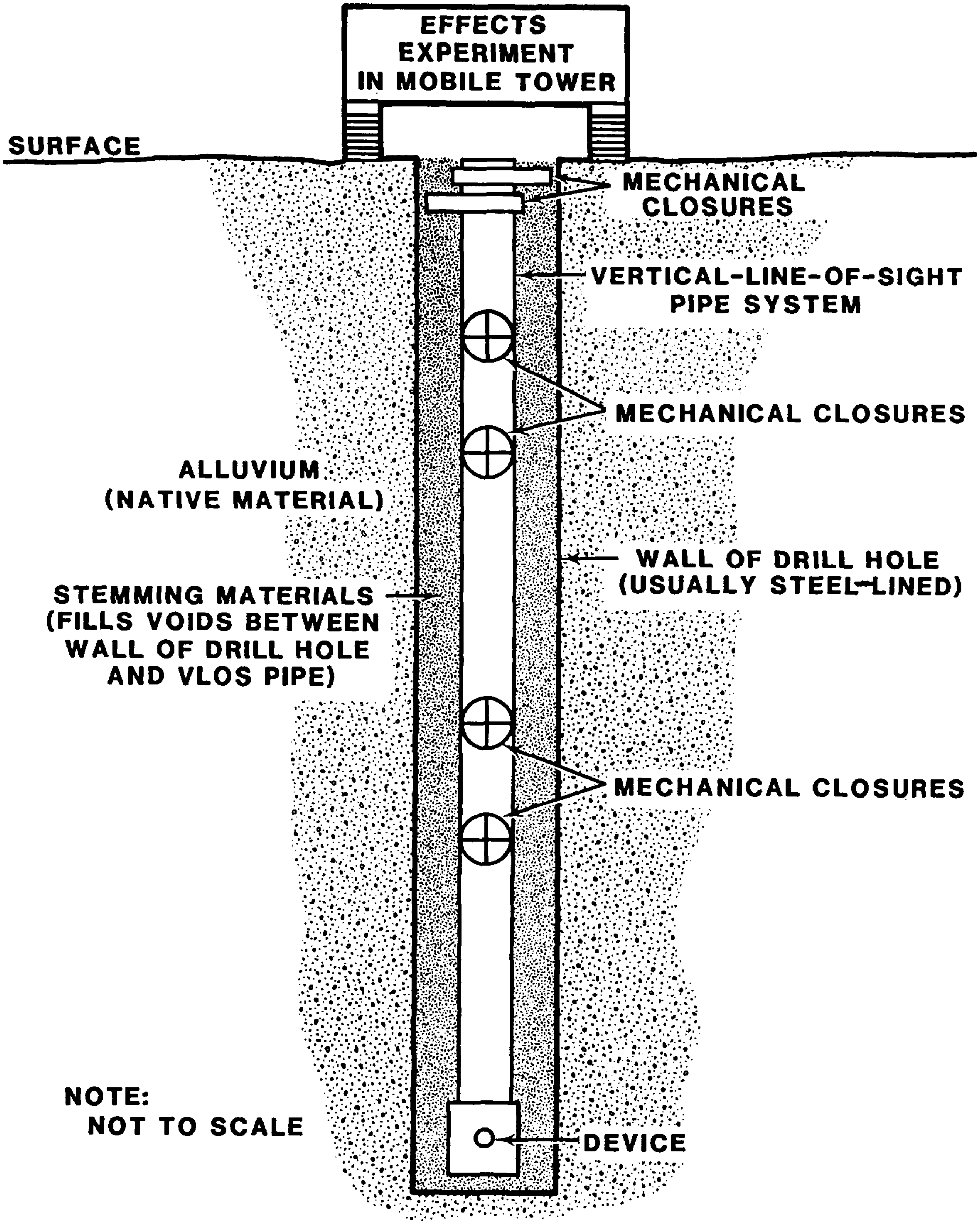

Figure 7. Vertical LOS pipe configuration.

2.2.2 Tunnel-Type Emplacement

Tunnel-type nuclear detonations were intended to be completely contained. The nuclear device was emplaced in a mined drift (tunnel) at a depth designed to contain the detonation. The native material at tunnel elevation for events covered in this report was ash-fall tuff. Chimneying of broken rock to the surface was rare for Rainier Mesa tunnel events, primarily because there was a layer of welded rhyolitic ash-flow tuff at and below the surface of Rainier Mesa. This tuff has a higher density than ash-fall tuff and is more competent (has more strength) than the alluvial material in Frenchman and Yucca Flats. Tunnel-type emplacements were in one of several configurations: at the end of a single horizontal tunnel into a mountain or mesa, at the end of a drift (tunnel) within a tunnel complex, at the end of a horizontal tunnel driven from a vertical shaft, or in a cavity mined from a horizontal tunnel or vertical shaft.

During the period covered by this report, the five tunnel-type emplacements included HLOS pipe systems placed in horizontal drifts in tunnel complexes (see Figure 8). Each device was placed close to the end of a drift inside a tunnel complex. An HLOS pipe system, including several mechanical closures and one or more test chambers (which contained effects experiments), were installed in the drift. The void space between the tunnel walls and the HLOS pipe was filled (stemmed) with different mixtures of grout as plugs and/or sand plugs out to a distance of several hundred feet from the device location. Two or more concrete plugs were keyed into the tunnel walls between the test chamber and the main tunnel of the complex entrance. The primary containment system was the closure of the tunnel in the stemmed area. Ground shock and expansion of gaseous cavity material exerted pressure on the tunnel walls and stemming materials to form a stemming plug (closing the tunnel and HLOS pipe). All electrical cables and other penetrations within the stemmed area

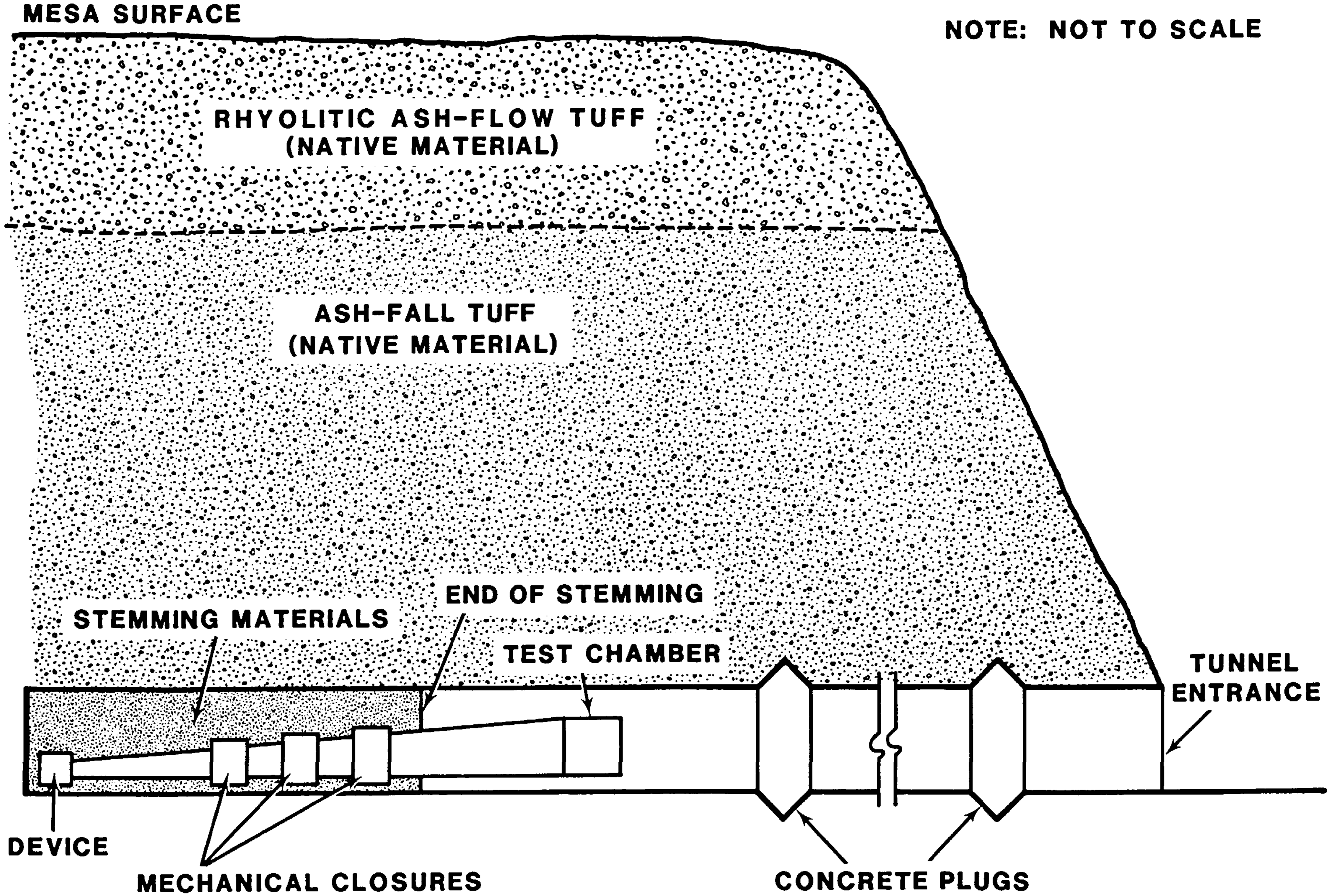

Figure 8. Horizontal LOS pipe configuration.

were gas blocked carefully to prevent or minimize seepage of radioactive gas through the stemming plug. The mechanical closures were designed primarily to protect effects experiments; however, they also had some effect on formation of the stemming plug. Concrete plugs were backup containment features. In the event the stemming plug did not contain radioactive gases, concrete plugs were designed to withstand the maximum expected pressure and temperature.

FC/DNA has led in development of tunnel containment systems and has maintained continuing research and development programs to improve containment of tunnel events.

2.3 DIAGNOSTIC TECHNIQUES

The transition from atmospheric to underground testing substantially reduced release of radioactive materials to the atmosphere and also required development of new device diagnostic techniques. On atmospheric tests, high speed photography recorded fireball growth and aircraft collected samples from the radioactive cloud for diagnostic measurement analyses. Because such systems could not be used on underground tests, several new diagnostic techniques were developed (some of which are discussed in the following subsections).

2.3.1 Radiation Measurements

Measurements of radiation from an underground detonation were made possible by developing a system of remote detectors and cabling to send signals to recording facilities located on the surface. Detectors utilizing various physical characteristics of the radiations to be measured were installed near the nuclear device. High-specification coaxial cable and connectors carried measurement signals to the surface where electronic equipment, film, and magnetic tape recorded the signals.

Detector signals were on the way to recording equipment in billionths of a second after a detonation, before detectors were destroyed. These measurement systems required the most advanced electronic technology available. Indeed, considerable research and development were necessary to acquire and refine these capabilities.

2.3.2 Radiochemical Measurements

Because clouds from atmospheric detonations no longer were available to sample for diagnostic purposes, techniques were developed to obtain samples of debris from underground detonations for radiochemical analyses and subsequent yield determinations. The first systems were radiochemical sampling pipes leading directly from the device emplacements to filtering equipment on the surface. These pipes required closure systems to prevent overpressure from venting radioactive effluent into the atmosphere after samples were collected.

While these systems functioned as intended for most detonations, the systems did not function properly during all tests, and some radioactive effluent was released into the atmosphere. Subsequently, regular use of radiochemical sampling pipes to the surface was discontinued for a time until technology improved.

A major radiochemistry sampling method which continued in use for shaft detonations was postevent core drilling. The objective of this drilling was to obtain samples of solidified radioactive debris, which had collected in a molten pool at the bottom of the cavity produced by the detonation. This method required and resulted in development of precise directional drilling techniques and several advancements in the science of core drilling.

2.4 EFFECTS EXPERIMENTS

DOD/DNA events were conducted primarily to obtain nuclear weapons effects data. The effects of blast and shock, thermal radiation and nuclear radiation had been investigated earlier during atmospheric and underwater tests. Military equipment, structures, and materials had been exposed to various nuclear effects. The transition to underground testing required development of new test techniques. One important new technology was simulation of high altitude (to exoatmospheric) conditions for radiation effects experiments.

This simulation technique involved placing experiments inside test chambers and providing a low pressure atmospheric condition from the nuclear device to the experiments. This was achieved by using large vacuum pumps to reduce pressure inside the steel LOS pipe to match the pressure of the desired altitude.

Experiments were passive or active. Passive experiments involved placing experiment equipment in the test chambers, exposing it to the desired nuclear environment, removing equipment, and analyzing it to obtain effects results. Active experiments utilized various sensors and high speed electronic recording equipment to obtain data. Many active (diagnostic) experiments also involved recovery and analysis to obtain effects results.

2.5 TUNNEL AND DRILLING AREA ACCESS REQUIREMENTS

Access to underground workings and drilling sites was controlled for a number of reasons. During construction, safety of both workers and visitors in these locations could have been jeopardized by carelessness or seemingly harmless activities of untrained and uncontrolled workers or visitors. When security-classified materials were in these locations, only personnel with appropriate security clearances were permitted access. The presence, or anticipated presence, of radioactive material in these locations required access control for radiological safety purposes. Access requirements established for the above purposes are discussed below.

2.5.1 Tunnel Access Control

During construction and preparations for a DOD event in a tunnel or other underground working, the tunnel superintendent was responsible to the REECo project manager for safety of personnel underground. From 1962 forward, Radsafe log books and tunnel log books usually were used to record names and radiation exposure information for only those persons entering a tunnel during postevent reentry and recovery operations. In the early 1970s, as a result of the Mine Safety and Health Act, tunnel log books were expanded to list all persons entering the tunnels (i.e., mining, drilling, Radsafe, etc.). Visitors and other personnel not assigned to work in the tunnel obtained permission for entry from the superintendent, or his representative, and were apprised of tunnel conditions and safety regulations. In the event of an accident or other emergency condition underground, the log book provided information on numbers of personnel and their locations underground.

When classified material was in the tunnel prior to a test event, and during initial reentry after an event, the DOD Test Group Director, or his representative, was responsible for entry and safety of personnel underground. Security personnel checked for proper security and entry clearances, and maintained records of all personnel entering the tunnel, and safeguarded classified material and the device. The check point was often well inside the portal thus allowing several activities to be conducted simultaneously.

Control of tunnel access reverted to tunnel management personnel after tunnel reentry and recoveries. Entry procedures and use of the tunnel log book, if appropriate, were then as discussed above.

Additional access controls were instituted for radiological safety purposes after an event or during construction and event preparations when radioactivity from a previous event could be encountered. Part or all of a tunnel complex could be established as a radiation exclusion (radex) area.

All persons entering radex areas were logged on Area Access Registers. Names and organizations represented were listed. Radiation exposures from reports for the year and quarter were listed upon entry. Self-reading pocket dosimeter measurements were added upon exit. This was to assure that personnel approaching radiation exposure guide limits would not be allowed to enter radex areas when they could accumulate exposures above guide amounts.

Before entry, personnel were dressed in anticontamination clothing and respiratory protection as needed for the particular radiological conditions in the tunnel. Upon exit, anticontamination clothing was removed, personnel were monitored for radioactive contamination, and decontamination was accomplished, if necessary.

2.5.2 Drilling Area Access Control

Access to drilling areas was controlled by the drilling superintendent and the DOD Test Group Director for the same reasons as controlling access to underground workings. During drilling of an emplacement shaft, and during postevent drillback operations to recover radioactive core samples, personnel safety and compliance with safety regulations were emphasized continuously.

During pre-event drilling activities, all visitors were required to contact the drilling superintendent before entry to the drilling site. Names of visitors and purposes of visits were entered in the daily drilling report, and it was assured that visitors had hard hats and understood safety regulations.

The laboratory which provided the device controlled access to the area, assisted by security force personnel when classified materials (including the nuclear device) were brought into the area for emplacement, as in similar tunnel operations. After the event, when the drill site was a radex area, during classified material removal, or during postevent drilling, both security and radiological safety access controls were in effect as discussed under "Tunnel Access Control."

2.6 INDUSTRIAL SAFETY CONSIDERATIONS

Implementation of an effective industrial safety program was an important part of any heavy construction operation. Mining and drilling operations had a particularly high accident potential. These operations at the NTS involved additional safety problems resulting from detonation-induced unstable ground conditions and potential for encountering toxic gases, explosive mixtures, and radioactivity.

Miles of underground workings were constructed. More depth of big holes (three-foot diameter or larger) were drilled than the known total drilled in the rest of the world. Directional and core drilling to recover radioactive debris samples after underground nuclear detonations advanced the science of these drilling techniques. These operations often were accomplished under unusual conditions with accompanying difficult safety problems.

However, the lost-time accident frequency for the NTS support contractor employing most of the NTS personnel (REECo) was only one-tenth of the frequency for the heavy construction industry at large (as determined by annual surveys and reports for 300 heavy construction corporations). This excellent safety record was attained by continuing attention to indoctrinating and training NTS personnel, investigating and determining causes of accidents at NTS, implementing and enforcing safety regulations, and, most important, maintaining the safety awareness of NTS personnel.

This was a joint effort by the DOE and DNA, and their predecessors, and by the many other government agencies and contractors at NTS. Administered by REECo, the safety program enjoined all NTS personnel to conduct operations safely, and was exemplified by signs on the portal of a typical DOD tunnel complex as shown in Figure 9, which includes "Safety With Production Is Our Goal."

The safety procedures for all NTS operations are voluminous and cannot be included in this report. Appendix C of this report is an example of pertinent safety procedures: General Tunnel Reentry Procedures for Department of Defense and Sandia Laboratory Tests. As these procedures indicate, several aspects of industrial safety are interrelated. Information on monitoring levels of radioactivity and personnel exposures to radiation is presented in the next section.

Monitoring of toxic gases and explosive mixtures was an important aspect of safety in underground workings, on drill rigs, and in drillhole cellars (enlarged first part of drillhole for valving and other equipment). Toxic gases and explosive mixtures were created by both the nuclear detonations and the mining and drilling operations. Draeger multi-gas detectors and MSA explosimeters were used to detect such gases. Fyrite or J&W

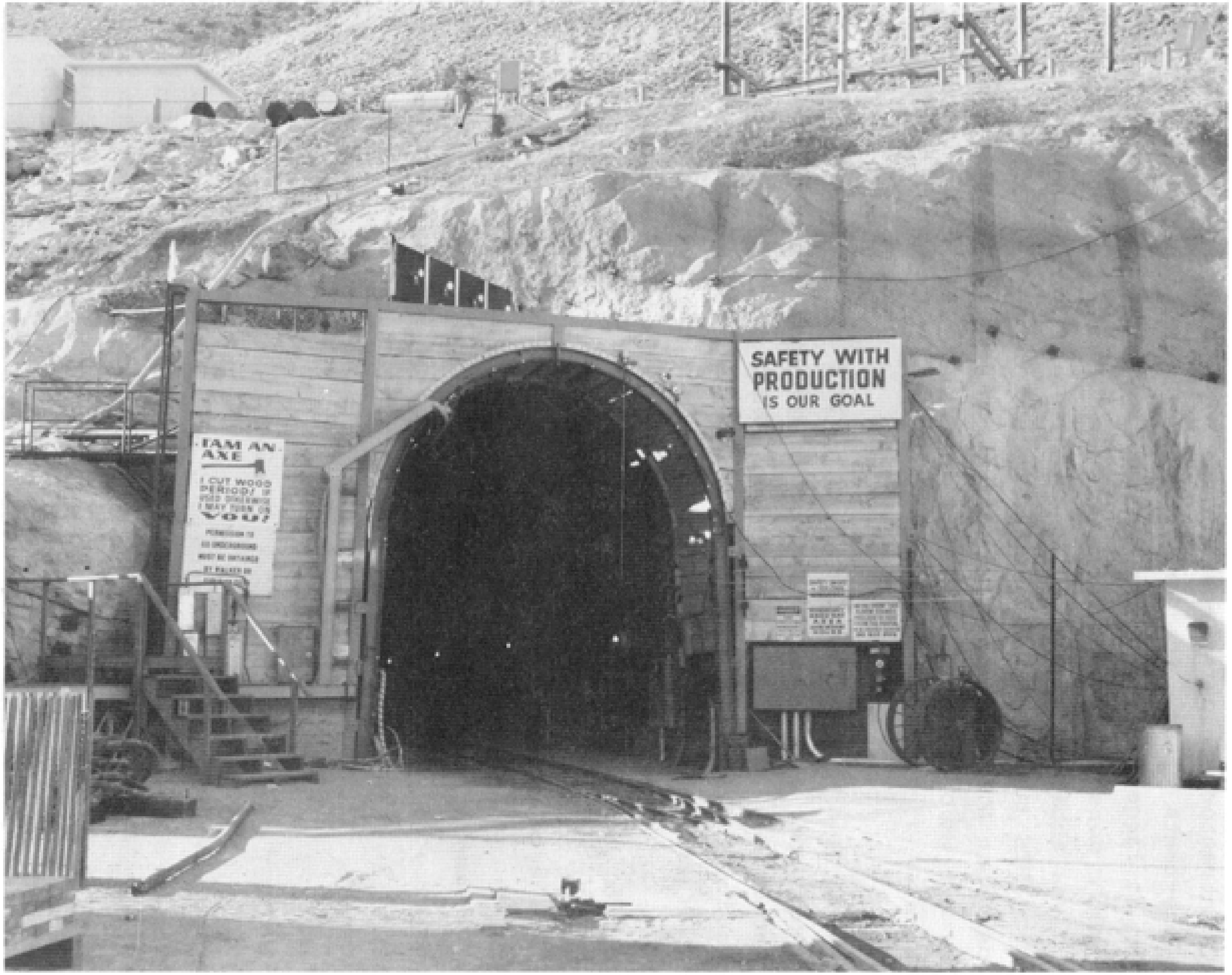

Figure 9. Portal of a typical DOD tunnel complex.

oxygen indicators were used to determine oxygen content of the working atmosphere. Requirements were that tunnel and drill rig breathing atmosphere contain at least 19.5 percent oxygen. During the period covered by this volume, it was required that the breathing atmosphere contain less than the following levels of toxic gases and explosive mixtures:

Gases	Maximum Concentration
Carbon monoxide, CO	50 ppm
Carbon dioxide, CO_2	5000 ppm
Nitric oxide plus nitrogen dioxide, NO + NO_2	25 ppm
Nitrogen dioxide, NO_2	5 ppm
Explosive mixtures	10% of LEL (lower explosive limit)

Procedures for controlling explosive mixtures and toxic gases after each test event are discussed in event chapters as appropriate.

2.7 RADIOLOGICAL SAFETY PROCEDURES

Procedures were developed in an effort to evaluate radiological, toxic, and other hazards, and protect workers and the public from unnecessary exposures. The following were the primary written procedures and implementation methods used at the NTS from 1969 through 1972.

2.7.1 U.S. Atomic Energy Commission, Nevada Test Site Organization - Standard Operating Procedure (NTSO-SOP), Chapter 0524, Radiological Safety.

Chapter 0524, which appears as Appendix D to this volume, defined responsibility and established criteria and general procedures for radiological safety associated with NTS programs. Some but not all of the major areas discussed are film badge procedures, radiation surveys, entry into controlled areas, and radiation exposure guides. Roles of the onsite REECo Radiological Sciences Department and the offsite EPA are defined in NTSO-SOP Chapter 0524.

2.7.2 Standard Operating Procedures for the Radiological Sciences Department, REECo.

These procedures were prepared and updated annually to address in more detail the radiological safety aspects discussed in the latest revision of NTSO-SOP Chapter 0524. The same major areas were discussed; but in a more specific manner.

2.7.3 Implementation of radiological procedures; required equipment, devices, and capabilities for monitoring radiation levels in the environment; and monitoring external and internal exposures of personnel.

Equipment and devices used for these purposes and necessary capabilities, were as follows:

A. Portable Radiation Detection Equipment

- Eberline PAC 4G (alpha)
- Eberline PAC 1SA (alpha)
- Jordan AGB-500B-SR Radector (gamma)
- Jordan AGB-10K-SR Radgun (beta and gamma)
- Eberline E-500B Survey Meter (beta and gamma)
- Technical Associates and Hanford Cutie Pie Survey Meter (beta and gamma)
- Technical Associates Juno Survey Meter (alpha, beta, and gamma)
- Precision Model P-111 Scintillator (gamma)

B. Air Sampling Equipment

- Model 102 semi-portable sampler
- Satellite sampler
- Hurricane high volume portable sampler (Gelman)
- Vacuum pump low volume portable sampler (Gelman)

C. Laboratory Analysis Capability

The Radiological Sciences Laboratory analyzed air, soil, water, surface swipe, nasal swab, urine, and wound swab samples for some or all of the following activities: gross alpha and beta, gross fission products, tritium, strontium-90, plutonium-239, and spectrographic analysis of specific gamma-emitting radionuclides. The laboratory also analyzed some of the above samples for nonradioactive materials, such as beryllium, through use of an emission spectrograph and by wet chemistry procedures. A spectrophotometer was used to analyze for other materials.

D. Monitoring of Personnel Exposures

The NTS combination personnel dosimeter and security credential holder was placed in use in 1966 to provide increased personnel dosimetry capability necessary to meet the radiation exposure problems associated with nuclear rocket testing and underground nuclear detonations. The holder, designed to accommodate a DuPont type 556 film packet, a fast neutron packet, and identification plate, criticality accident components, the security credential, and a snap-type clip, had capabilities for determining beta, gamma, x-ray, thermal neutron, fast neutron, high range gamma, and high range neutron doses. Components for criticality accidents (unintentional or accidental nuclear fissioning of device critical materials) included materials which could detect and measure neutron and gamma radiation exposures above the ranges of the film packets. The DuPont 556 film packet contained two component films, type 519 (low range) and type 834 (high range). Gamma exposure ranges of the two components were 30 mR to 10 R and 10 R to 800 R, respectively. The NTS combination personnel dosimeter and security credential holder is shown in Figure 10.

Film badges were exchanged routinely each month for all individuals, and upon exit from a radex area when it was suspected that an individual had received 100 mR or more of exposure.

Personnel entering radex areas also were issued self-reading pocket dosimeters which indicated accumulated exposure. Upon exit, pocket dosimeter readings were entered on Area Access Registers and added to the yearly and quarterly accumulated exposures from the automated daily NTS radiation exposure report for use until results of film packet processing were included. Pocket dosimeter readings only were estimates because such readings were less accurate than the doses of record determined after processing film packets.

This use of Area Access Registers helped to maintain personnel exposures below the whole-body exposure guides in Chapter 0524: 3000 mrem per quarter and 5000 mrem per year. Personnel with exposures from the report plus any pocket dosimeter reading since the report in excess of 2500 mrem per quarter or 4500 mrem per year were advised not to enter radex areas, and their supervisory personnel were so notified.

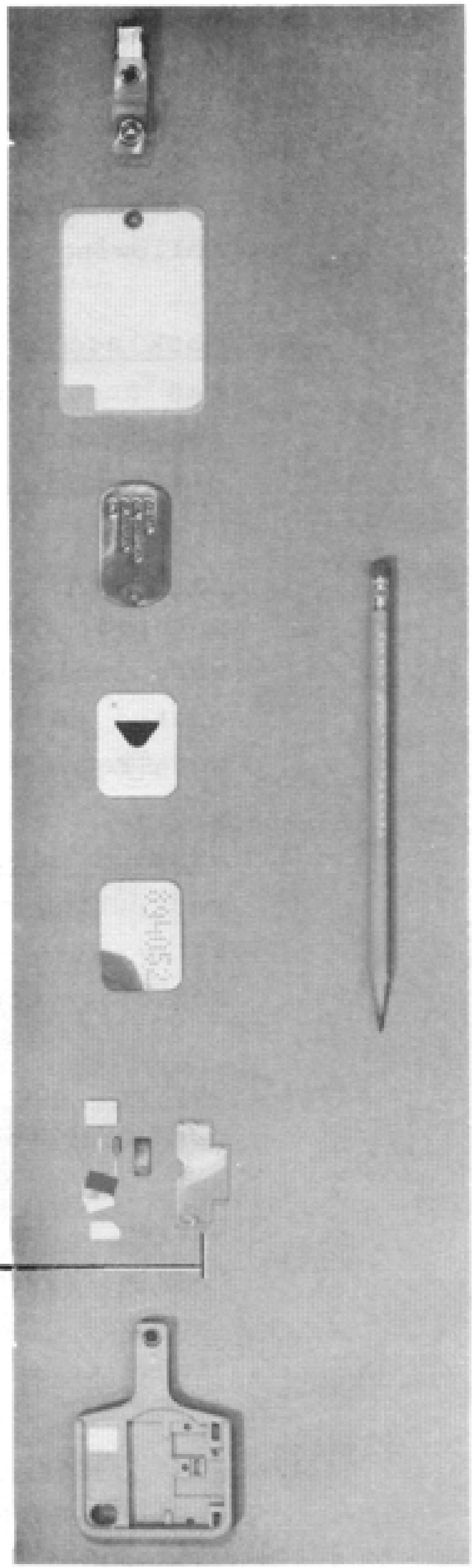

Figure 10. NTS combination personnel dosimeter and security credential holder.

2.7.4 Additional methods used for control of radex areas and to prevent spread of contamination to uncontrolled areas were as follows:

A daily log book was maintained by Radsafe monitors for each radex area location. These logs were used to record the following information:

A. Work accomplished: Where people worked and what work was accomplished were briefly described. Any unusual conditions, such as equipment failure and operational difficulties, were listed.

B. Visitors: First and last names of visitors were entered. Their destination and reason for their visit were included where possible. Time they entered and exited the area and results of personnel monitoring were recorded.

C. Unusual occurrences: Any unusual events which occurred during the shift were recorded. Included in this entry were accidents, high-volume water seepage, or any other occurrence of an unusual nature.

D. Surveys and samples: Information collected was recorded as follows:

   Survey type - Routine or Special*
   Sample type - Routine or Special*

   *Indicate requester's name for Special type.

E. Date and signature: The date and shift were entered at the beginning of the work period and the log book was signed before leaving the shift.

Personnel leaving radex areas removed anticontamination clothing and equipment and placed them in special containers for later laundering or disposal at the designated NTS burial site. Personnel then were monitored to assure radiation levels were below those listed in Part I of Appendix D, AEC NTSO-SOP Chapter 0524, "Radiological Safety." Personnel decontamination was accomplished if radiation levels were above specified limits. Decontamination usually was accomplished by vacuuming, removing radioactive particles with masking tape patches, washing hands or localized skin areas with soap and water, or showering with soap and water.

Vehicles and equipment removed from radex areas were monitored to assure that they met acceptable radiation levels for release on the NTS (25 mrad/h beta plus gamma at contact and 250 cpm non-swipeable alpha). Limits for release of vehicles and equipment off the NTS were 0.3 mrad/h beta plus gamma radiation at contact and no detectable alpha activity. Vehicles and equipment normally were decontaminated by vacuuming and steam cleaning with water or detergent solutions.

2.8 TELEMETERED MEASUREMENTS OF RADIATION LEVELS

Beginning in the early 1960's, various applications of radiation measurement telemetry were developed at the NTS to determine radiation levels at critical underground and surface areas following nuclear detonations. Multi-detector systems with range capabilities from 0.5 mR/h to 500 R/h and from 10 mR/h to 10,000 R/h continuously monitored locations of concern after being emplaced and calibrated prior to each test event. Ion chamber detectors were hard-wire-linked by telephone trunk lines to exposure rate meters at a central console in CP-2. Detector locations were as far as thirty-five miles from this console.

These remote radiation monitoring systems provided data for reentry personnel participating in radiation surveys and recovery operations after a nuclear device detonation. The systems aided in substantially reducing exposure of personnel involved in reentry programs and were useful in detecting any venting or leaking of radioactive effluent to the atmosphere from an underground detonation.

2.8.1 Telemetry Systems in Use

The radiation telemetry systems developed and used had specific applications depending upon distance, terrain, environment, and operational needs. The detection units, systems, and components being studied and developed or in use in 1969 were the following:

A. Remote Area Monitoring System (RAMS)

The principal piece of equipment used to form a RAMS was the RAMP-4. The RAMP-4 was a multi-channel, hard-wire-linked, remote area gamma radiation monitoring (telemetry) system, designed and modified by Radsafe and produced by Victoreen Instrument Corporation. It consisted of a probe (Figure 11) which used a Neher-White radiation sensing element, hardwire communication to the readout console (Figure 12) (up to 35 miles), and components of Victoreen Radector instruments with recorders for readout.

The readout covered six logarithmic decades (two three-decade scales) to provide a usual range of 1 mR/h to 1,000 R/h with a relative accuracy of ± 15 percent over the temperature range of -10°F to 150°F.

Figure 11. Neher-White RAMS probe.

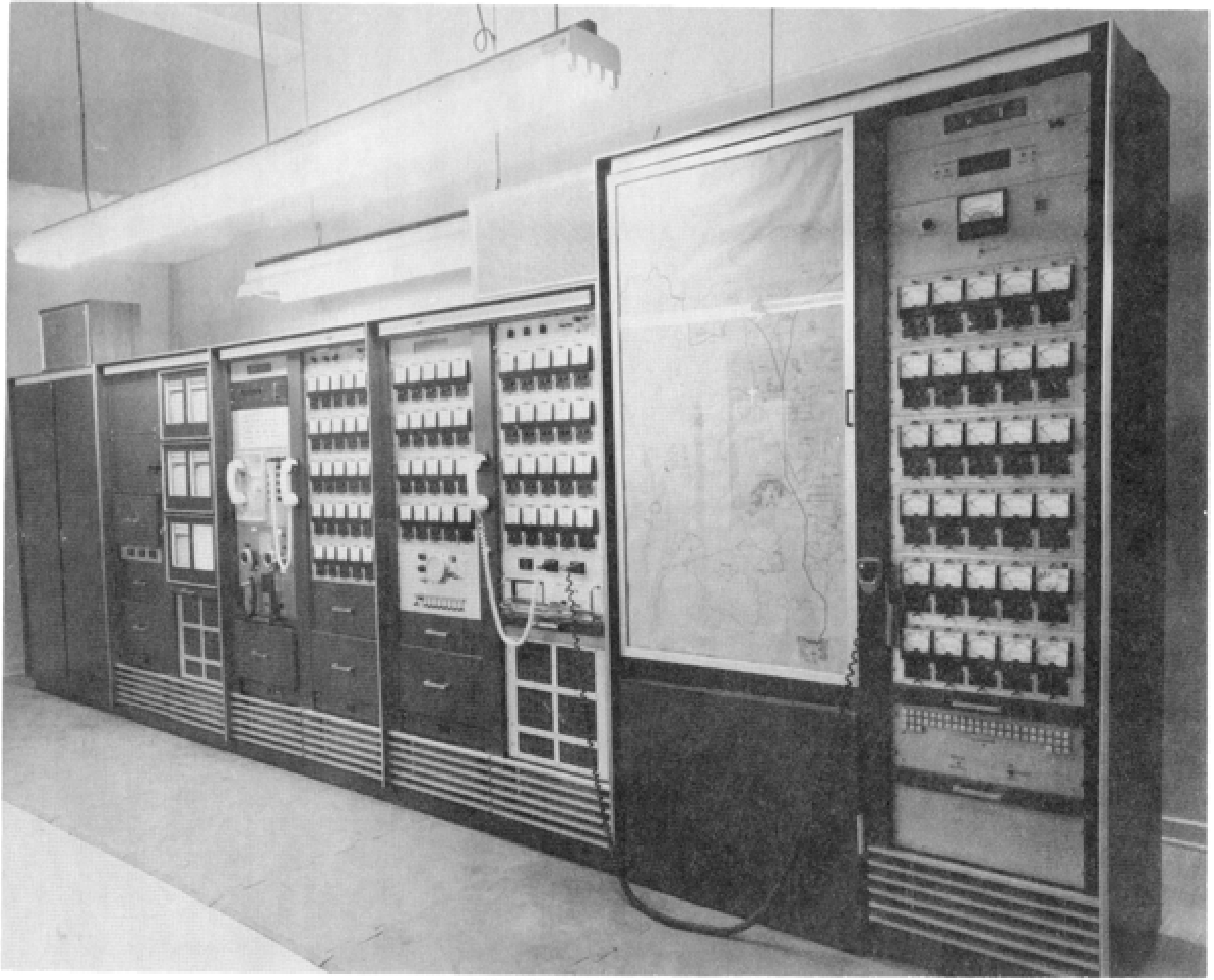

Figure 12. RAMS readout console.

A permanent array of 21 telemetry stations throughout the NTS, as designated by the AEC, was maintained and operated continuously. Temporary telemetry arrays for DOD events varied between 20 and 50 stations depending upon the area or tunnel event location.

B. Digital Data System

The Digital Data System was a multi-channel, radio-linked, remote gamma radiation monitoring system. The detection unit and communications consisted of a RAMP-4 probe hard-wire-linked to a field trailer where signal data were digitized and transmitted via UHF to a trailer at the CP. The readout consisted of a typewriter, a punched tape, and a digital printer, and all three operated simultaneously to provide current operational data, permanent records, and the capability for reproduction of data at any future time.

This system was used primarily in remote areas where hard-wire communication did not exist. Communications between the field trailer and the CP were accomplished via NTS radio net 3 and a UHF net assigned prior to each event for use during installation and check-out, in addition to use during and after each event.

C. Well Logging Unit

This unit was a Jordan ion chamber gamma detector with a glass-head thermister capable of obtaining gamma radiation or temperature measurements either separately or simultaneously. It was used at drill sites for post-event hole radiation and temperature measurements. Radiation detection ranges were from 0.5 mR/h to 500 R/h and temperature measurement ranges were from 0°F to 350°F.

2.8.2 Remote Area Radiation Detection Monitoring Support

Approximately two hundred remote radiation detector channels were available to continuously monitor radiological conditions and assess exposure rates before the test area was entered after detonation. Approximately 20 detector units were positioned in the test area before a shaft-type event. Detectors were placed in circular arrays at specified distances and azimuths from SGZ which varied with device yield and predicted wind direction (See Figure 13). Variable numbers of detectors (between 20 and 50) were used aboveground and underground during tunnel-type events. An additional 20 to 35 permanently established remote radiation detector stations operated continuously at living areas, work areas, and other designated locations throughout NTS (Figure 14). The large number of remaining channels was available as required at additional detector locations, for other test events in preparation, an/or substitute channels. Event-related telemetry detectors operated from zero time until it was determined that release of radioactivity probably would not occur, or until any released radioactivity had decayed to safe or near-background levels at the telemetry stations. For some events, readout locations were positioned near the forward control point (FCP) or at locations where telephone lines were available.

Radiation telemetry data were supplemented with information collected through a mobile air sampling program. Model 102 air sampling units were used to obtain samples of any radioactive effluent released at event time or during the postevent drilling operations. Test groups used an average of 21 units during each test event. Prior to each nuclear detonation experiment, these samplers were placed at specified locations around the test area and remained in position until drillback operations were completed or the Test Group Director authorized removal of the units.

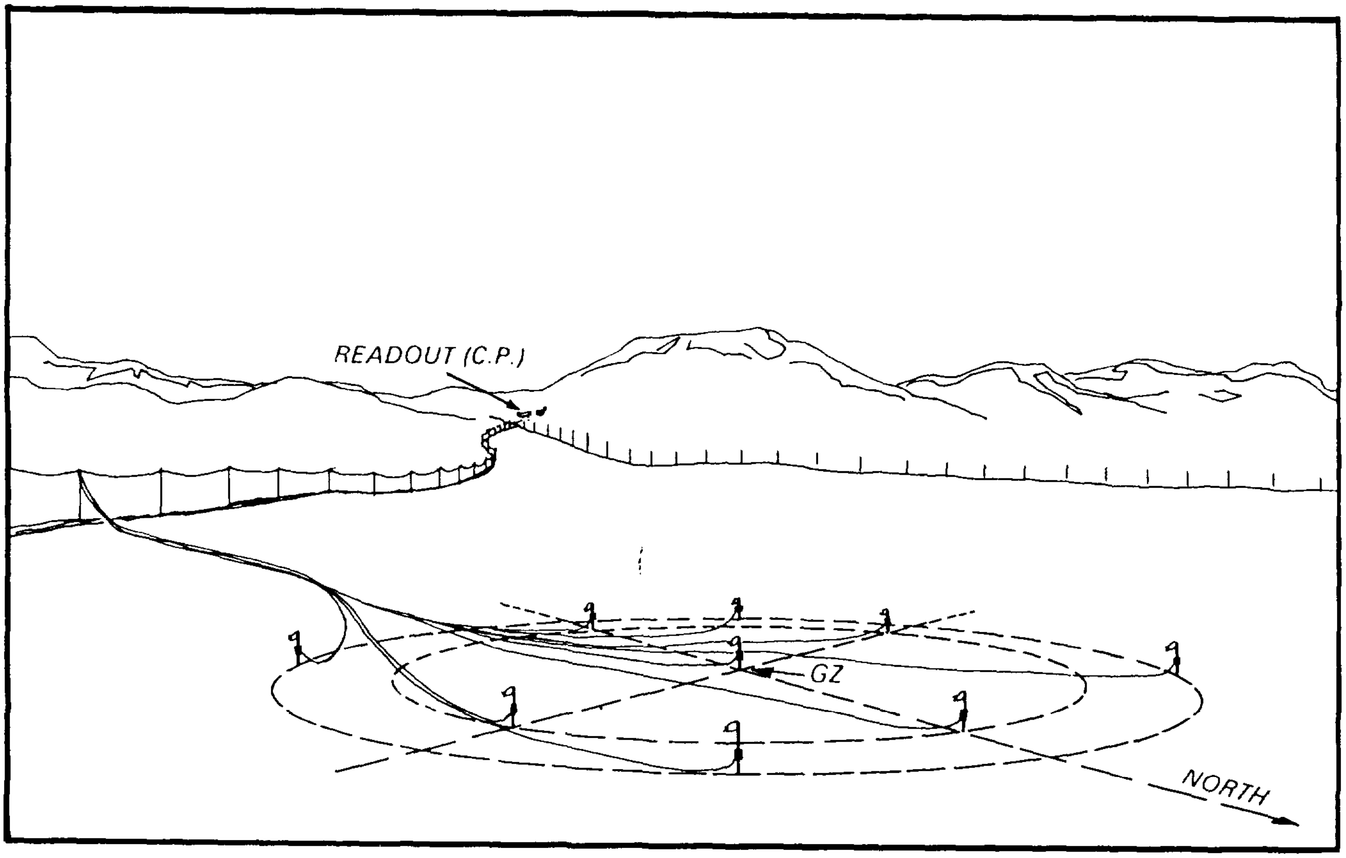

Figure 13. Typical remote radiation detection monitoring system for shaft-type emplacement site.

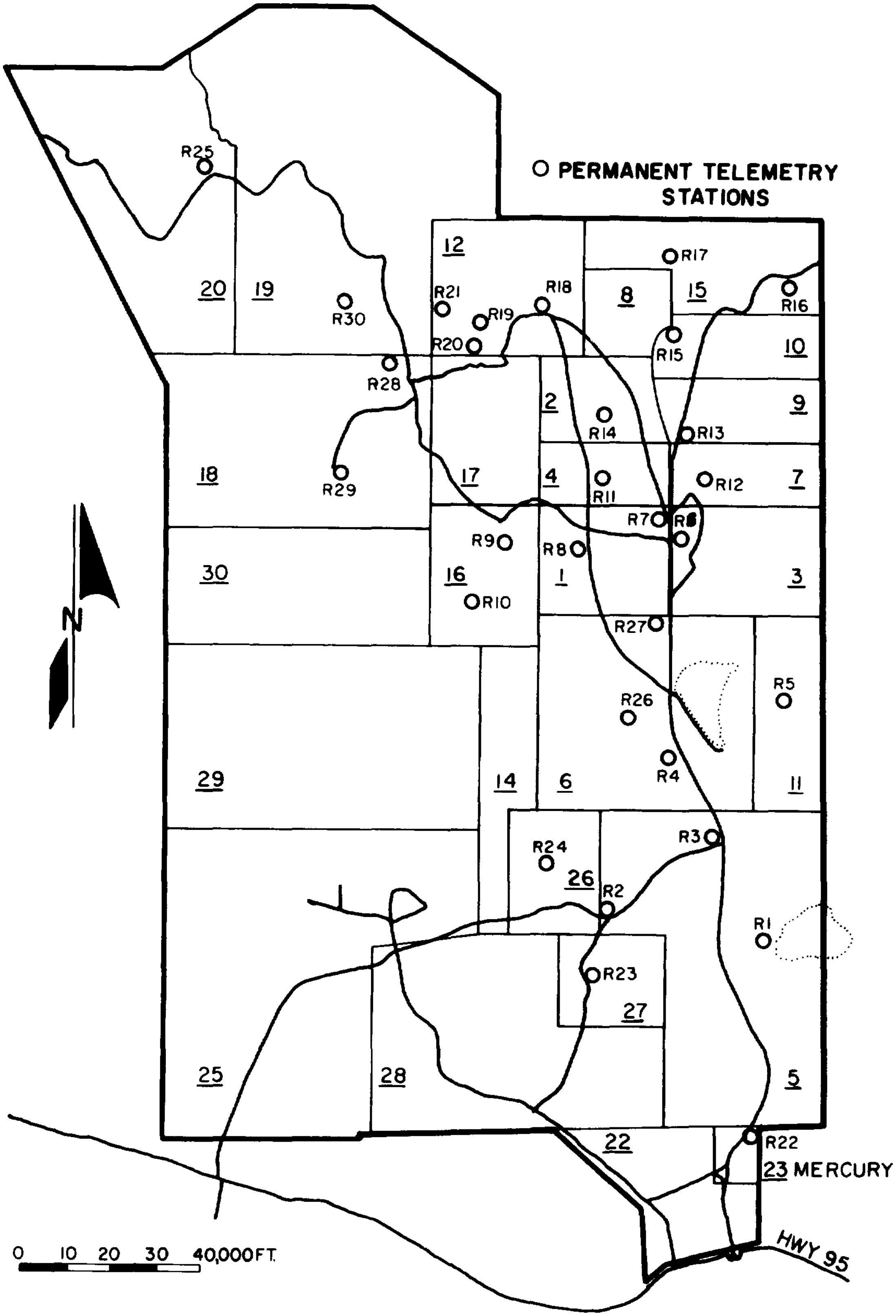

Figure 14. Typical permanently-established remote radiation detector stations operated continuously throughout NTS.

2.9 AIR SUPPORT REQUIREMENTS

Direct support was provided to NTSO by AFSWC for DOD underground tests, and other Air Force organizations provided support under AFSWC control as described in Section 1.3.2 of this report. Less air support was required, however, as the probability of venting radioactive effluent to the atmosphere decreased with development of more effective containment techniques.

2.9.1 Changes in Air Support Requirements

After atmospheric testing ended in 1962, use of Air Force cloud sampling aircraft to obtain cloud samples for yield determinations was only feasible for AEC cratering events where radioactive effluent clouds were anticipated. Passage of the radioactive effluent through variable amounts and temperatures of rock and other media selectively retained some radionuclides underground, and changed known ratios of fission products previously used during analysis of atmospheric detonation cloud samples. The value of analyzing particulate and gaseous cloud samples to determine characteristics of a detonation decreased.

The first change in cloud sampling and tracking support was to a lighter Air Force aircraft, the U-3A, with an Air Force pilot and EPA monitor. The EPA monitor also performed aerial monitoring of selected locations near surface ground zero and along the path of any effluent cloud. This air support later was performed by EPA and contractor personnel in their own aircraft.

Perimeter sweeps continued to be conducted daily by Air Force and Security personnel, during reasonable flying weather, to assure that unauthorized vehicles were not entering the NTS over rough terrain or around security barricades on secondary roads. L-20 aircraft used prior to 1968 were replaced with helicopters and other aircraft thereafter. Air security sweeps of the immediate test area were conducted for a few hours before each detonation to assist in clearing the test area and to assure that unauthorized vehicles were not approaching it from directions not controlled by manned security stations.

Air support for photography missions during test events and initial radiation surveys after each event did not change. Helicopters with Air Force pilots generally were used with contractor and military photographers and Radsafe monitors.

2.9.2 Radsafe Support for Indian Springs Air Force Auxiliary Field (ISAFAF)

Radsafe support facilities had been established at Indian Springs Air Force Base (ISAFB), about 20 miles southeast of Mercury, during atmospheric nuclear device testing series. During 1962 tests, and subsequent DOD underground tests requiring support aircraft staged from ISAFB (which became ISAFAF in 1968), REECo provided all radsafe support functions available at the NTS. This included monitors stationed at the ISAFAF radsafe quonset facility and a complete stock of film dosimeters (badges), radiation detection instruments, and anticontamination clothing and equipment for use by aircrews and ground crews.

Radsafe monitors issued and exchanged film dosimeters (badges), issued self-reading pocket dosimeters, provided anti-contamination clothing and respiratory protection equipment, monitored aircraft and personnel after events, decontaminated personnel, and assisted ground crew personnel with decontamination of aircraft.

2.9.3 Radsafe Support for Helicopters

Although ISAFAF radsafe support extended to all participating aircraft, special helicopter radsafe procedures were implemented because these aircraft landed at NTS and staged from helicopter pads located east of Mercury Highway at the CP area and near a Test Controller's FCP established for a particular underground event. Helicopter pilots usually landed at these locations, and were briefed at the CP or particular FCP regarding their scheduled missions or other operational missions.

If the mission involved possible contamination of the aircraft, Radsafe monitors lined the floor of the aircraft with plastic, or kraft paper, and masking tape to facilitate decontamination. Pilots and crew members were dressed in anticontamination clothing and provided with film badges, pocket dosimeters, and respiratory protection equipment if airborne radioactive material was anticipated and oxygen masks were not worn.

Upon completion of missions, helicopters returned to the landing pads where they were decontaminated by Radsafe monitors. Pilots and crew members were decontaminated at an adjacent forward Radsafe base station, or at CP-2, where the pocket dosimeters were collected and read and film badges were exchanged if exposures of 100 mR or more were indicated by pocket dosimeters.

CHAPTER 3

MINUTE STEAK EVENT

3.1 EVENT SUMMARY

The MINUTE STEAK event was conducted at 1102 hours Pacific Daylight Time (PDT) on 12 September 1969 with a yield less than 20 kt. The device, which was fielded by LRL, was emplaced 867 feet beneath the surface in a 66-inch diameter cased hole (U11f). Figure 15 shows the trailer park layout for this event. An LOS pipe to the surface was used for this event. The test objective was to expose materials and equipment to a nuclear detonation environment in order to determine response characteristics. Government agencies and contractors conducted 22 projects to obtain the desired information.

Radioactive effluent began to seep from the SGZ area at H+5 minutes. Twenty-three minutes after detonation, a subsidence crater formed and seepage of radioactive effluent through fissures began. Cal-Seal was used to fill the SGZ pit and one fissure, and dirt was used to cover the other fissure. No radioactive effluent was detected offsite.

3.2 PREEVENT ACTIVITIES

3.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all MINUTE STEAK event activities in Area 11, subject to controls and procedures established by the Test Manager and NTSO. AEC and AEC contractor responsibilities were in accordance with established AEC/DOD agreements or were the subject of separate

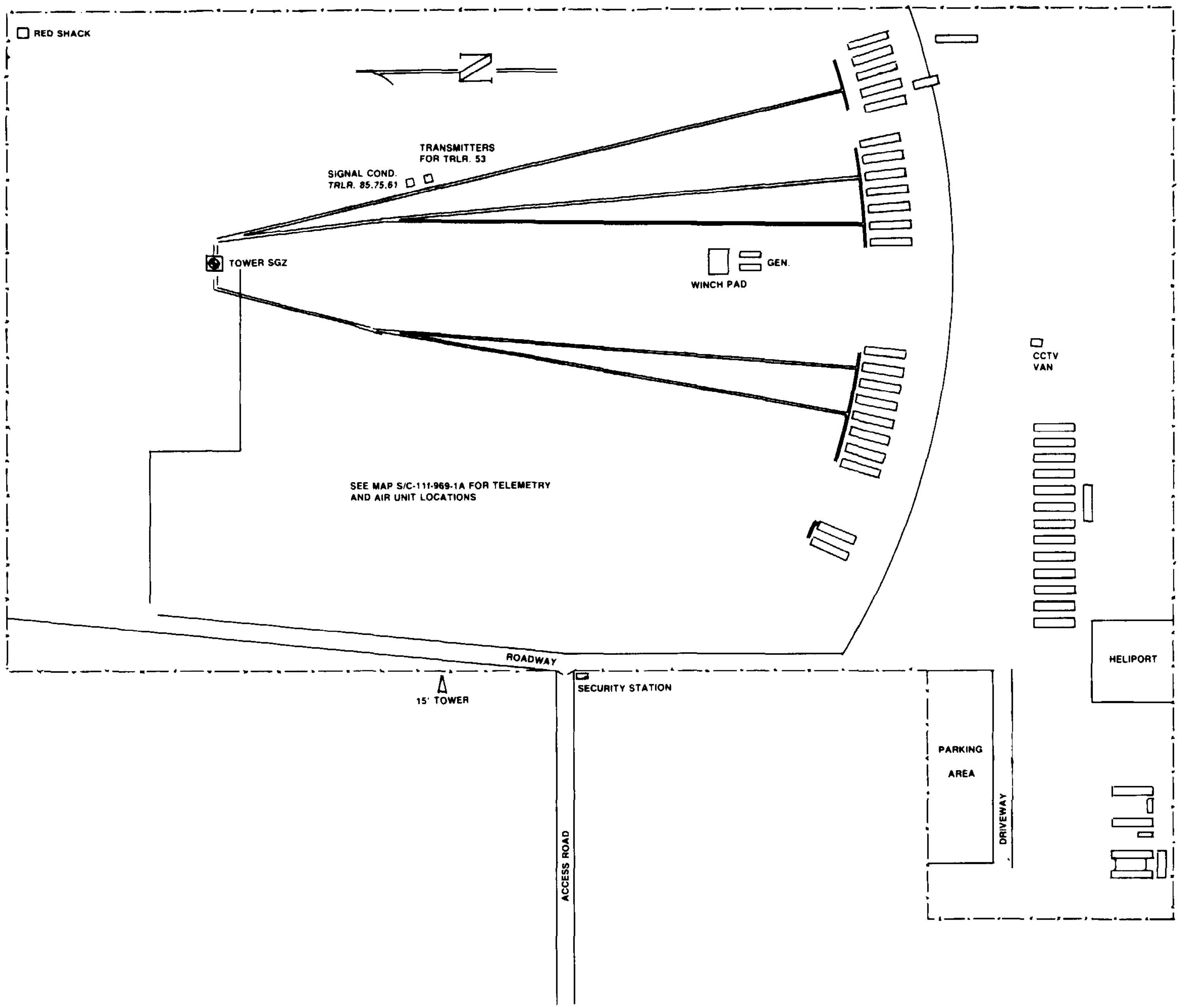

Figure 15. MINUTE STEAK Event trailer park layout.

action between Test Command, DASA, and the AEC Nevada Operations Office. Reentry and recovery programs were conducted by Sandia Laboratories, Albuquerque (SLA).

The LRL Test Group Director was responsible to the Test Manager for radiological safety within a 3,000-foot radius of SGZ. This responsibility was in effect from the time the device was moved to the zero site until device detonation. After device detonation, the Test Manager relieved the LRL Test Group Director of responsibility which then was delegated to the DOD Test Group Director.

3.2.2 Planning and Preparations

A. Radiological Safety Support

A "Detailed MINUTE STEAK Support Plan" was prepared and issued for implementation to participating agencies prior to the event. Procedures for radiation exposure and contamination control were in accordance with requirements of responsible DOD and SLA personnel. Radsafe provided monitoring and equipment support, air sampling, and telemetry. Test area maps showing appropriate reference points were prepared. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

A geophone system was used to monitor postevent seismic disturbances. Signals were routed to CP-1 for audible and recorded readout.

A mobile issue facility stocked with anticontamination clothing, respiratory protection equipment, and dosimetric devices was positioned, prior to the event, at the security barricades near the FCP. A personnel and vehicle decontamination facility was established adjacent to the mobile issue facility. All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance. Anticontamination equipment and materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

One base station with a team of Radsafe monitors was positioned at the FCP. This station was used to "suit up" the surface reentry and recovery parties before their departure from the FCP. If contamination was encountered, this station would be used to monitor and decontaminate personnel and equipment as they returned from the controlled area.

B. Telemetry and Air Sampling Support

RAMS units for the MINUTE STEAK event were located as shown in Table 2. Figure 16 shows locations relative to SGZ of stations 1 through 13 and 18.

Twelve air sampling units were placed at 30-degree intervals on a 1,000-foot radius from SGZ beginning at 0° azimuth.

PHS personnel had positioned air sampling units at 98 routine offsite locations, and ten personnel were on duty for surveillance activities.

Table 2. MINUTE STEAK Event RAMS unit locations.

Station	Location (from SGZ)
1	Near SGZ
2	SGZ experimental tower
3	600 feet at 0° azimuth
4	600 feet at 45° azimuth
5	600 feet at 90° azimuth
6	600 feet at 135° azimuth
7	800 feet at 168° azimuth
8	800 feet at 178° azimuth
9	800 feet at 191° azimuth
10	800 feet at 203° azimuth
11	600 feet at 225° azimuth
12	550 feet at 270° azimuth
13	600 feet at 315° azimuth
14	2,000 feet at 0° azimuth
15	2,000 feet at 90° azimuth
16	2,000 feet at 180° azimuth
17	2,000 feet at 270° azimuth
18	250 feet at 0° azimuth

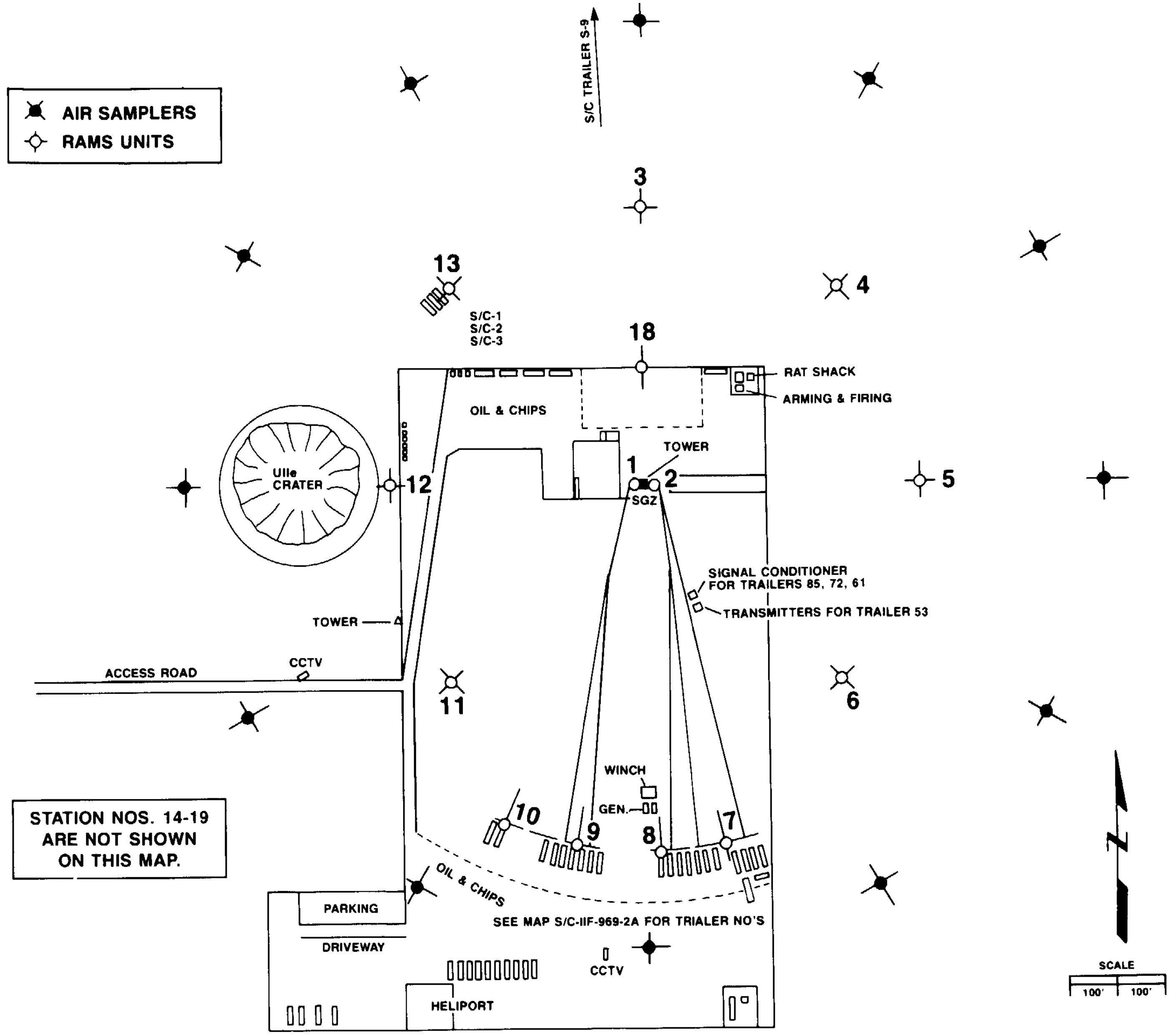

Figure 16. MINUTE STEAK Event RAMS unit locations.

C. <u>Security Coverage</u>

Device security procedures were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." All personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges, or issue and return of muster badges. After area control was established, all through traffic was diverted by use of screening stations.

D. <u>Air Support</u>

Two USAF UH-1F helicopters and crews were available. One was used for security sweeps and the other for aerial photography. In addition, the USAF provided a U-3B and crew for cloud tracking, and the PHS provided a Turbo Beech for cloud sampling. The EG&G/NATS aircraft was on standby at McCarran Airport in Las Vegas.

3.2.3 Late Preevent Activities

Button up activities were performed by personnel representing DASA, Harry Diamond Laboratories (HDL), Lockheed Missile and Space Corp. (LMSC), General Atomic (GA), Naval Research Laboratory (NRL), Massachusetts Institute of Technology (MIT), EG&G, Moleculon Research Corp. (MRC), LRL, Naval Ordnance Laboratory (NOL), and SLA. A test execution time of 0700 hours on 12 September was proposed at a readiness briefing held at 1430 hours on 11 September. The date and time were initially acceptable; however, the time was later revised to 1000 hours. The next readiness briefing was scheduled for 0600 hours on 12 September. Security sweeps of the closed area began at 2200 hours on 11 September.

3.3 EVENT-DAY AND CONTINUING ACTIVITIES

The final readiness briefing was conducted as scheduled at 0600 hours on 12 September. At that time, conditions were confirmed to be good for the planned zero time of 1000 hours. Permission to arm the device was requested and granted at 0806 hours. After performing the arming function, the team exited the area and the countdown began. A delay in countdown occurred due to cable problems.

MINUTE STEAK zero time was 1102 hours on 12 September 1969.

3.3.1 Test Area Monitoring and Radioactive Effluent Release Situations

Telemetry measurements began at 1103 hours on D-day. The maximum gamma radiation reading (60 R/h) for this event was measured by RAMS unit No. 2 at 1103 hours on D-day. This unit was located inside the experimental tower and readings occurring between zero time and H+5 minutes were as expected due to activation products.

The first seepage of radioactive effluent occurred through a leak at surface ground zero at H+5 minutes. At H+23 minutes, crater subsidence occurred creating two fissures, one on the northeast edge and one on the southwest edge of the crater, which released radioactive effluent. Leakage at SGZ was stopped at approximately H+4 hours by pouring Cal-Seal in and around the SGZ pit. The maximum gamma radiation reading obtained at the fissure on the northeast edge was 2 R/h at 1940 hours. By 1950 hours, the fissure had been covered with dirt and readings had decreased to 5 mR/h. The fissure on the southwest side of the crater read 400 mR/h at 1945 hours before it was filled with Cal-Seal. Another reading was taken at 2100 hours after the Cal-Sealing operation was completed and a measurement of 45 mR/h was obtained.

With the exception of RAMS units Nos. 2 and 18, all units had decreased to background radiation levels by 1903 hours on D-day. RAMS unit No. 18 returned to background at 0333 hours on 15 September; but in the case of unit No. 2, although readings were steadily decreasing, 1.6 mR/h was the final measurement (due to activation) when telemetry coverage was discontinued on 16 September at 1230 hours.

Analysis of air samples collected from zero time to H+4.5 hours indicated the presence of radioiodines, xenon-133, xenon-135, and xenon-138.

3.3.2 Aerial Monitoring

Aerial monitoring was performed by two PHS monitors in an Air Force U-3B. A PHS Turbo Beech (Vegas 8) was used to perform additional monitoring and sample the release.

A. U-3B Tracking Mission

The U-3B entered the area at 1110 hours and began tracking the radioactive effluent cloud. At 1230 hours, the cloud was located over Papoose Lake area and a reading of 0.3 mR/h was obtained. A track, starting at 1240 hours, did not detect any radioactive effluent along the Mercury Highway and along a heading east from mid-Groom Lake and south to Emigrant Valley. A subsequent search east and north of Papoose Lake produced no reading above background. At that time, it appeared that the cloud was entirely over Papoose Lake and was stationary. The mission was terminated at 1213 hours after making a final pass over SGZ at 5500 feet MSL.

B. Vegas 8 Sampling Mission

Vegas 8 entered the area at 1112 hours and made several passes north of SGZ to determine the direction of cloud movement. It was subsequently determined that the cloud was moving through Nye Canyon in a northeasterly direction toward Papoose Lake. At 1140 hours, a pass two miles from SGZ and normal to cloud trajectory indicated that the leading edge had passed that location. A spiral descent performed four miles north of SGZ on a 30° azimuth revealed the cloud top to be at 10,000 feet MSL with activity extending to ground elevation (approximately 5,000 feet). At 1154 hours, a reading of 6.0 mR/h was obtained at 6,300 feet MSL.

A sampling path was next established at 6,300 feet MSL one mile south of Papoose Lake (12 miles northeast from SGZ) and normal to cloud trajectory. The leading edge of the cloud, which was moving at a speed of approximately 12 miles per hour, crossed the sampling path at 1202 hours. A peak reading of 0.1 mR/h was recorded for this pass. A second pass at 1206 hours indicated a cloud width of 1.5 miles and a peak reading of 0.14 mR/h at 30° azimuth. Measurements obtained during a third pass at 1216 hours indicated the cloud was 2.5 miles wide, and the peak radiation level was 0.4 mR/h.

Between 1221 hours and 1248 hours, several passes were made across the cloud. The peak reading on each pass was 0.5 mR/h. Reports from the U-3B tracking mission indicated the cloud had not moved north of the Papoose Lake area. Therefore, based on this information, it was assumed the cloud had stopped or the transport speed was very low.

Due to fuel considerations, Vegas 8 deviated from the sampling path to locate the trailing edge of the cloud. At 1252 hours, a sampling pass parallel to, and two miles south of, the original path was performed. A peak reading of 0.15 mR/h was obtained on a 30° azimuth. Another pass parallel to, and four miles south of, the original sampling path was performed at 1258 hours. A peak reading of 0.1 mR/h was obtained six miles south of Papoose Lake on a 30° azimuth. A pass at 1300 hours five miles south of, and parallel to, the original sampling path indicated no activity. The trailing edge was assumed to be between five and six miles south of Papoose Lake (7-8 miles from SGZ) at 1300 hours.

Cloud sampling indicated the MINUTE STEAK event released inert gases and their daughter products. The cloud moved northeast to the Papoose Lake area where it apparently stopped. Because of the slow cloud transport speeds and relatively short half-lives of the radionuclides involved, it was concluded that detectable concentrations would not reach the offsite area.

3.3.3 Initial Radiation Survey and Experiment Recovery Activities

The initial radiation survey began at 1151 hours and was completed at 1235 hours on D-day. All team members were dressed in anticontamination clothing and respiratory protection equipment. The maximum radiation reading obtained during this survey was 300 mR/h at the perimeter fence northeast of the crater at 1210 hours. Table 3 shows results of the initial survey. No alpha radiation was detected.

Film recovery teams (dressed in anticontamination clothing) entered the trailer park at 1240 hours. They were followed at

Table 3. MINUTE STEAK Event initial radiation survey data.

Time (PDT)	Location (from SGZ)	Gamma Exposure Rate (mR/h)
1151	Road 5Y Stake 12 (3.31 miles SW)	0.03
1152	Road 5Y Stake 15 (2.6 miles SW)	0.03
1153	Road 5Y Stake 18 (1.89 miles SW)	0.03
1154	Watsonville (Area 5)	0.03
1154	Road 11B Stake 1 (0.95 miles SW)	0.03
1155	Road 11B Stake 2 (0.71 miles W)	0.03
1156	1/4 mile east of Stake 11B-2 (0.46 miles W)	1.5
1157	Entrance to trailer park	2.0
1200	Trailer park	0.7
1201	West trailer	1.0
1204	Perimeter fence west of tower	8.0
1204	Perimeter fence west of crater	8.0
1205	East trailer	0.7
1207	Perimeter fence northwest of crater	12.0
1210	Perimeter fence north of crater	80.0
1210	Five cable trays	1.7
1210	Perimeter fence northeast of crater	300.0
1212	Perimeter fence east of crater	20.0
1215	Perimeter fence east of tower	7.0
1218	Closed circuit television No. 2	0.4
1220	Base of tower (east)	50.0
1230	West Cal-Seal line	2.0
1235	West Cal-Seal line	0.8

1445 hours by the tower recovery team. These team members (also "dressed out") entered the tower to perform damage and hazards evaluation. When this had been successfully completed, experiment recovery was authorized. Personnel representing NOL, LMSC, NRL, LRL, GA, and Nuclear Defense Laboratory (NDL) recovered their respective experiments until 2136 hours when Radsafe personnel secured the area for the night.

3.4 POSTEVENT ACTIVITIES

3.4.1 Experiment Recovery Activities

Experiment recoveries were conducted routinely from 12 to 24 September. There was no increase in radiation levels; the maximum concentration of toxic gas detected was 100 ppm carbon monoxide on 23 September during removal of a closure system; and no explosive mixtures were detected. The Radsafe base station was deactivated and the MINUTE STEAK operation was completed on 24 September 1969.

3.4.2 Postevent Drilling

No postevent drilling was performed on this event.

3.4.3 Industrial Safety

All explosives, electro-explosive components, solid propellants, toxic material and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224)
2. AEC Manual 500 Series for the Nevada Test Site

3. Individual Safe Operating Procedures (by experimenter organization)
4. MINUTE STEAK Safety Regulations

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DOD Safety Coordinator.

The area enclosed by the U11f fence was designated a hard hat area. Hard hats were required to be worn and foot protection in the form of safety boots, safety shoes, or toe guards was strongly recommended.

A written standard operating procedure was required for each operation involving explosives, toxic material, radioactive material, or any other operation with the potential for personal injury. Each individual involved in the project was required to be knowledgeable of the contents of the procedure.

Checks were made during each shift for toxic gases and explosive mixtures. These measurements were recorded in the monitors' log book. Industrial safety codes, including specific codes for drilling, were established by REECo and were emphasized during all operations.

3.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1103 hours on 12 September 1969 and ended on 16 September at 1230 hours. The maximum gamma exposure reading detected was 60 R/h at RAMS unit No. 2, located at SGZ on the experiment building at 1103 hours on 12 September.

The initial survey began at 1151 hours and ended at 1235 hours on 12 September. The maximum gamma exposure rate detected was 300 mR/h at a location northeast of SGZ at the perimeter fence. No alpha radiation was detected. The maximum gamma exposure rate detected was 2 R/h at fissures at the northeast edge of SGZ at 1940 hours on 12 September.

The maximum concentration of toxic gas detected in the entire operation was 100 ppm carbon monoxide on 23 September during removal of a closure system. No explosive mixtures were detected.

No whole body external or internal organ exposures were received which exceeded the established limits.

Personnel exposures received during individual entries to the MINUTE STEAK event from 12 September 1969 to 23 September 1969 are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	383	275	9
DOD Participants	148	230	6

No radioactivity above background levels was detected offsite by ground and aerial monitoring teams or by ground-based exposure rate recorders either after the detonation or during subsequent sample recovery operations.

It was the opinion of the PHS that no radioactive contamination of the offsite area resulted from this event.

CHAPTER 4

DIESEL TRAIN EVENT

4.1 EVENT SUMMARY

DIESEL TRAIN was detonated at 0900 hours Pacific Standard Time (PST) on 5 December 1969. The LASL-furnished device, which had a yield less than 20 kt, was emplaced in tunnel U12e.11 at a vertical depth of 1,386 feet (Figure 17). This event was a weapons effects test designed to study the response of equipment and materials exposed to a nuclear detonation environment. Government agencies and contractors conducted 19 projects to obtain the desired information. The event was successfully contained.

4.2 PREEVENT ACTIVITIES

4.2.1 Responsibilities

Safe conduct of all DIESEL TRAIN project activities in Area 12 was the responsibility of the DOD Test Group Director. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Test Command, DASA, and the AEC Nevada Operations Office.

Project agencies were responsible for designing, preparing, and installing their experiments, or delivering them to the installation contractor for subsequent placement. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

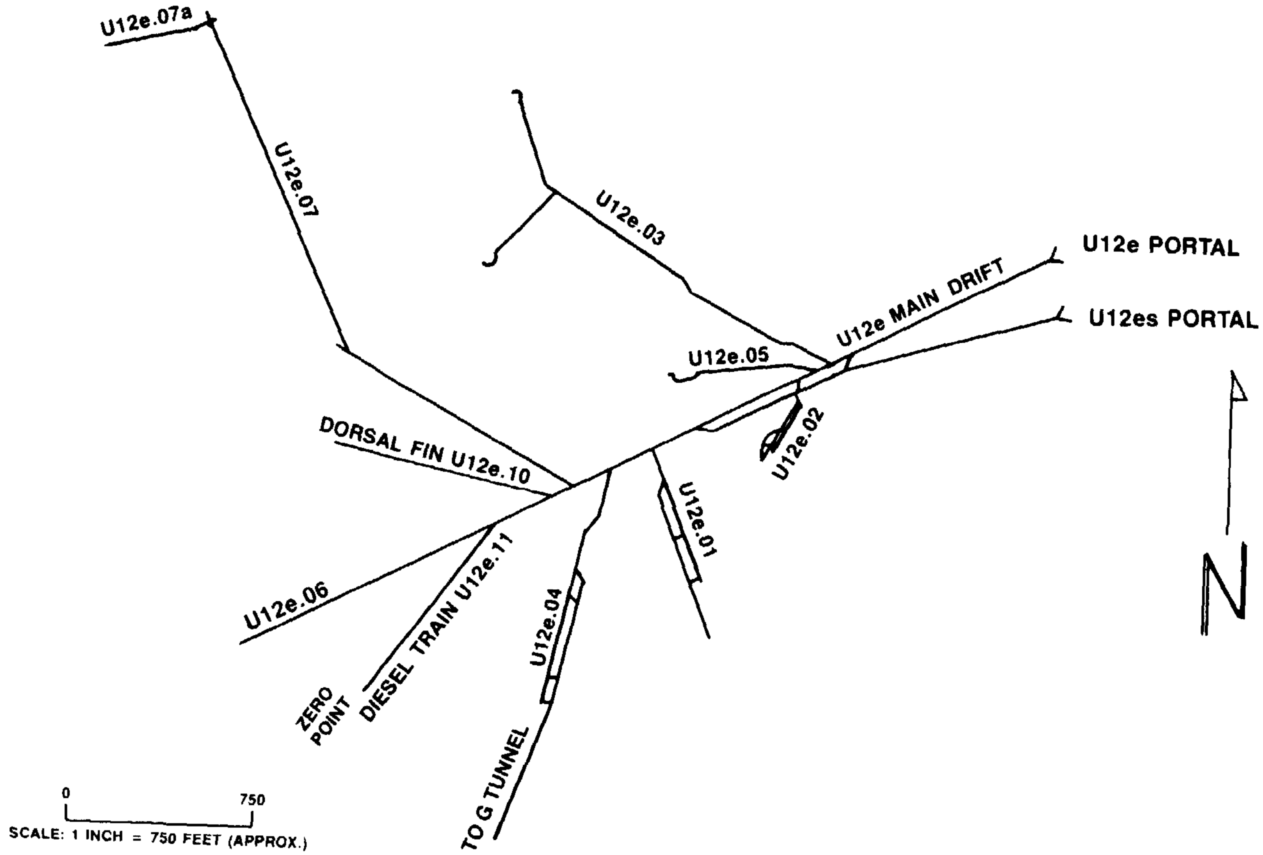

Figure 17. DIESEL TRAIN Event tunnel layout.

In accordance with provisions of NTSO-SOP Chapter 0524, "Radiological Safety," the LASL Test Group Director was responsible for radiological safety within a 6,000-foot radius of ground zero (GZ). This responsibility was in effect from device emplacement until device detonation. At that time, the Test Manager relieved the LASL Test Group Director of responsibility and delegated responsibility to the DOD Test Group Director. Device safety and security procedures in the GZ area were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

4.2.2 Planning and Preparations

A. Tunnel Facilities Construction

The U12e.11 drift originally had been mined for DIANA MIST, which was postponed. No drift modifications were required for DIESEL TRAIN except for mining a few new alcoves adjacent to the test chambers. Alcoves in the U12e.11 drift were employed for power supplies, signal conditioning equipment, vacuum pumps, and working space.

DIESEL TRAIN was the first event to use a multiplex system designed to control and monitor the reentry ventilation valves and fans and the portal and tunnel electrical power distribution system. Previously, these functions were performed using numerous timing signal pairs to the manned forward monitor station where a monitor and control panel were installed.

B. Radiological Safety Support

Procedures for radiation exposure and contamination control during this event were in accordance with requests of responsible DOD and SLA representatives. Radsafe provided required monitoring and equipment support, air sampling, and telemetry arrays.

Detailed radiological safety reentry plans ("DIESEL TRAIN Reentry Plan") were prepared and issued for implementation to participating agencies prior to the test. Reference markers and air sampling equipment were positioned in the test area. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial surface radiation surveys, perform aerial surveys by helicopter, and participate in reentry parties, as needed. Radsafe personnel also were standing by at the FCP prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support

Forty-eight RAMS units provided surface and underground coverage for the DIESEL TRAIN event as shown in Table 4 and Figures 18 and 19.

Four M-102 air sampling units were located as shown in Table 5.

Table 4. DIESEL TRAIN Event RAMS unit locations.

Station	Location
	SURFACE
1	At e portal
2	At es portal
3	300 feet at 337° azimuth from e portal
4	250 feet at 25° azimuth from e portal
5	425 feet at 90° azimuth from e portal
6	225 feet at 340° azimuth from es portal
7	300 feet at 250° azimuth from e portal
8	245 feet at 303° azimuth from e portal
9	125 feet at 45° azimuth from es portal
10	300 feet at 102° azimuth from es portal
11	300 feet at 180° azimuth from es portal
12	300 feet at 237° azimuth from es portal
13	300 feet at 286° azimuth from es portal
14	Between filters
15	On the west blower stack
16	On the east blower stack
17	2,250 feet at 63° azimuth from station No. 6
18	2,500 feet at 102.5° azimuth from station No. 6
19	1,100 feet at 128° azimuth from station No. 6
20	1,655 feet at 254° azimuth from station No. 6
21	2,500 feet at 329° azimuth from station No. 6
22	200 feet at 180° azimuth from e.10 cable hole No. 2
23	220 feet at 90° azimuth from e.10 cable hole No. 2
24	On e.10 cable hole No. 2
25	225 feet at 270° azimuth from e.10 cable hole No. 2

Table 4. (Concluded)

Station	Location
	SURFACE (Concluded)
26	250 feet at 0° azimuth from e.10 cable hole No. 2
27	570 feet at 180° azimuth from SGZ
28	700 feet at 80° azimuth from SGZ
29	430 feet at 330° azimuth from SGZ
	UNDERGROUND
30	560 feet into the U12e.11 drift
31	156 feet into the U12e.11 drift
32	605 feet into the U12e.06 drift
33AT*	605 feet (buried) into the U12e.06 drift
34AT*	495 feet (buried) into the U12e.06 drift
35	495 feet into the U12e.06 drift
36	900 feet into the U12e.12 drift
37	240 feet into the U12e.10 drift
38	800 feet into the U12e.06 drift
39	150 feet into the U12e.06 drift
40	4,100 feet into the main drift
41	150 feet into the U12e.04 drift
42	3,475 feet into the main drift
43AT*	3,475 feet (buried) into the main drift
44	3,425 feet into the main drift
45	2,885 feet into the bypass drift
46	1,850 feet into the bypass drift
47	50 feet into the es drift
48	50 feet into the main drift

*Buried

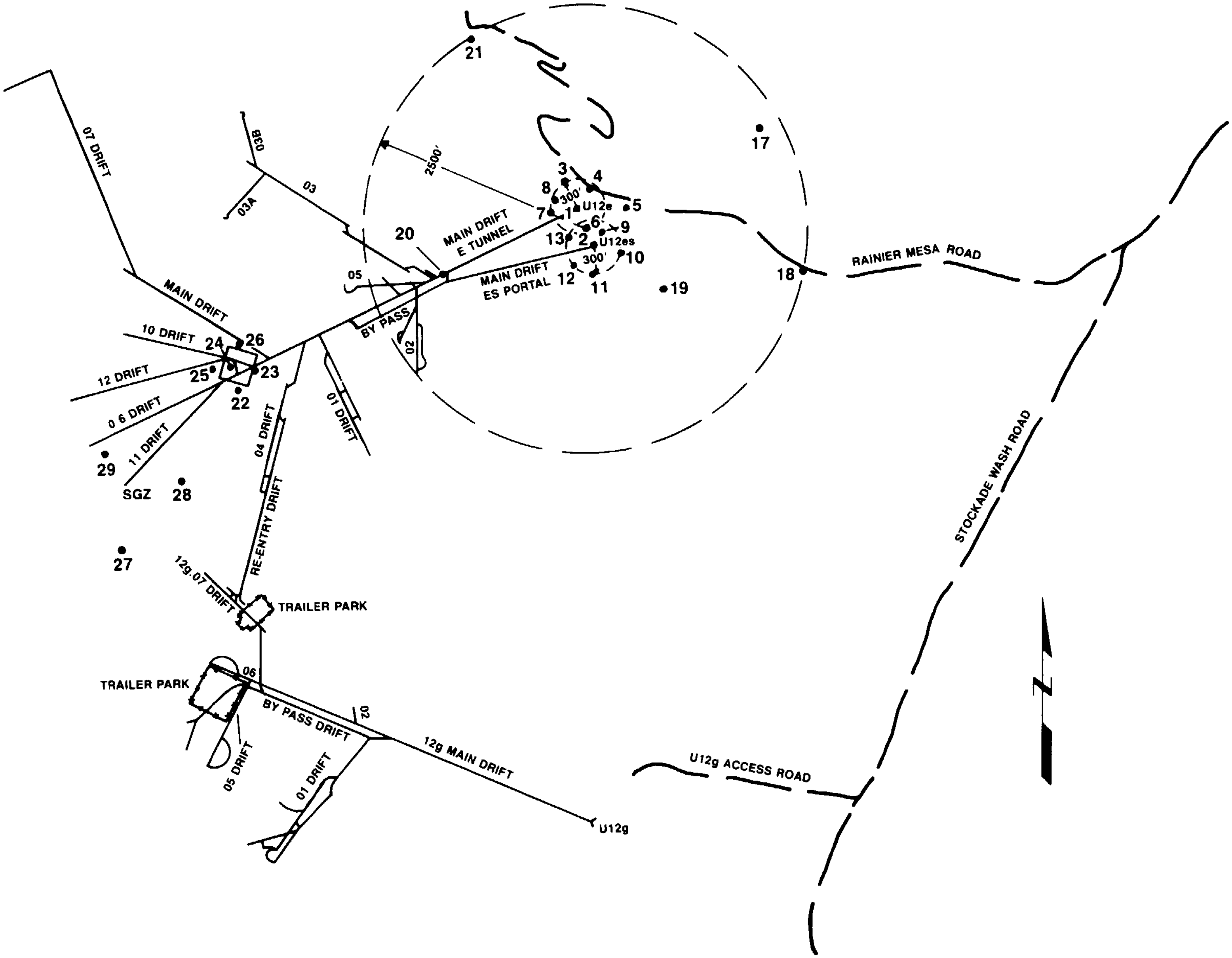

Figure 18. DIESEL TRAIN Event surface RAMS unit locations.

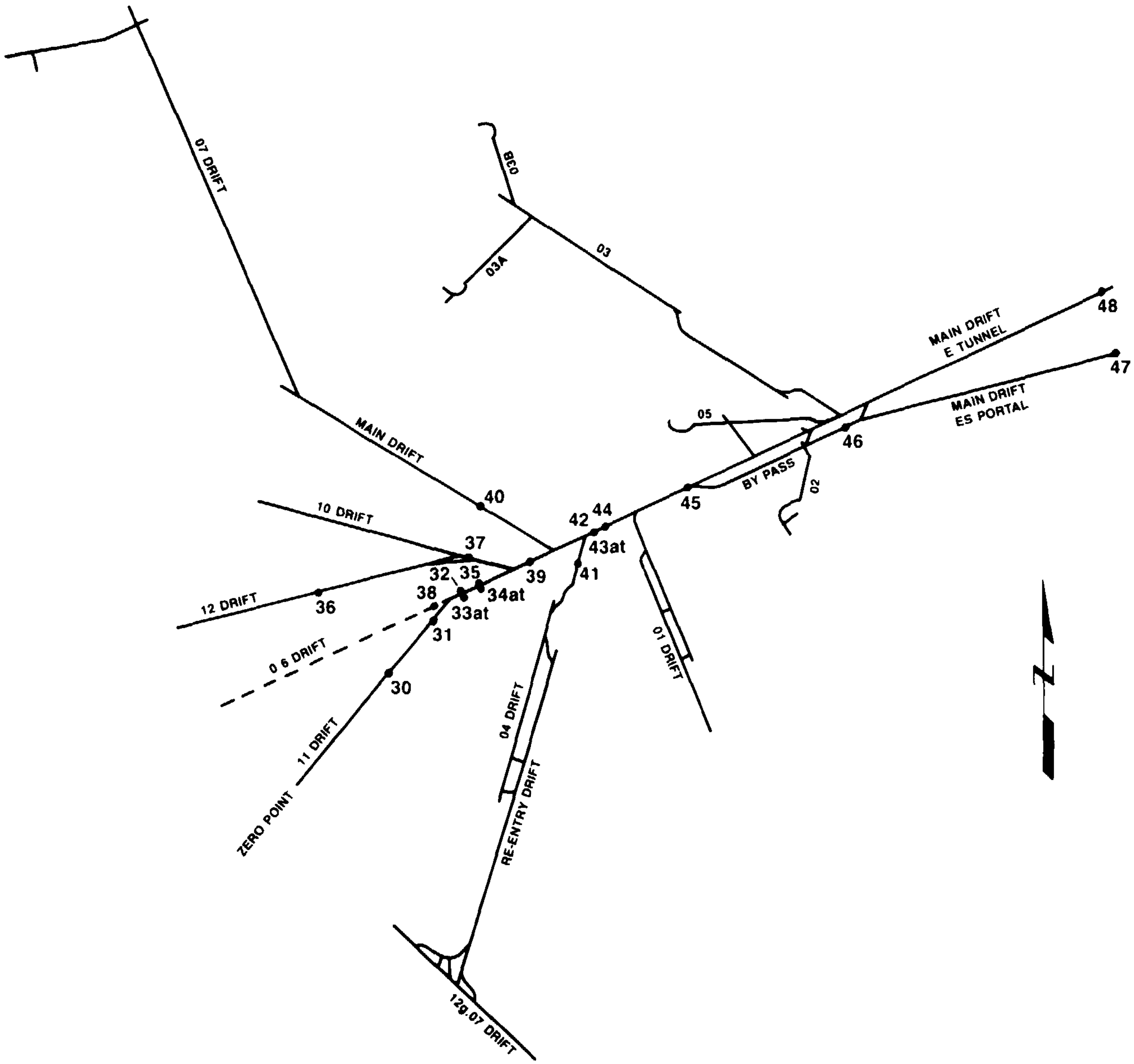

Figure 19. DIESEL TRAIN Event underground RAMS unit locations.

Table 5. DIESEL TRAIN Air sampling unit locations.

Station	Location
1	75 feet northeast from U12es portal
2	50 feet northeast from U12e portal
3	220 feet at 90° azimuth from U12e cable hole No. 2
4	180 feet at 315° azimuth from U12e cable hole No. 2

The Pagoda sampling trailer was used to sample the vent lines. Eight sampling heads were used, with four samplers located before the filter boxes and four located after the filter boxes. All of the cartridges were of the standard activated charcoal type.

Air samplers were positioned at 101 routine PHS stations in the offsite area.

D. Security Coverage

Device security coverage was in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." All persons entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges, or issue and return of muster badges. After area control was established, all through traffic was diverted by use of screening stations.

In accordance with the "Test Manager's Operations Plan," contractors and agencies were to have all personnel not connected with this event out of the controlled area before the final security sweep began.

E. Air Support

The U.S. Air Force provided two UH-1F helicopters with crews. One helicopter was used to perform preevent security sweeps and event photography, and the other was used for aerial photography or in support of the Test Manager, if needed. The USAF also provided a U-3B aircraft and crew to be used by PHS personnel for cloud tracking. An additional cloud-tracking aircraft, the EG&G/NATS Martin 404, was on standby at McCarran Airport in Las Vegas. The PHS provided two Turbo Beech aircraft for cloud sampling; however, only one was airborne at event detonation time. The other was on standby at McCarran Airport in Las Vegas.

4.2.3 Late Preevent Activities

A final dry run was held on 3 December in preparation for a scheduled zero time of 0900 hours on 4 December. At the 1430-hour readiness briefing on 3 December, winds were blowing toward Las Vegas which indicated that unless wind direction changed there would be little chance of meeting the scheduled 0900-hour zero time. On 4 December at 0435 hours, a power decrease on the Mesa occurred, causing all trailers run by electric motor generators to lose power. It was subsequently decided at a readiness briefing held at 0500 hours that the combination of power loss and increasingly poor weather conditions were cause for rescheduling DIESEL TRAIN for 5 December at 0900 hours. An additional readiness briefing was held at 1430 hours on 4 December and conditions appeared favorable to meet scheduled test execution.

Routine security sweeps and experimenter button up activities again were performed.

4.3 EVENT-DAY ACTIVITIES

Security sweeps were conducted between 0100 and 0450 hours. The final readiness briefing was held at 0500 hours with no change in scheduled test execution. Upon approval by the Test Manager, the device was armed and the arming party exited the area at 0630 hours. A security sweep at 0700 hours confirmed that the closed area was clear of all unauthorized personnel.

At about 0815 hours, an Air Force helicopter crashed near

Desert Rock Air Strip. No personnel were seriously injured and only photo coverage capability for the Test Manager was affected.

DIESEL TRAIN zero time was 0900 hours on 5 December 1969.

4.3.1 Test Area Monitoring

Telemetry coverage began at 0901 hours with all surface RAMS units reading background initially and with no increases thereafter. The maximum initial underground RAMS unit reading was also the maximum reading for all telemetry coverage during this event. RAMS unit No. 31 measured 350 R/h at 0901 hours on D-day. Only three underground units (Nos. 30, 31, and 32) detected radiation levels above background, and these levels had decreased to 19 mR/h, 27 mR/h, and background, respectively, by the time telemetry coverage was discontinued at 1315 hours on 7 December 1969.

4.3.2 Initial Surface Radiation Surveys and Experiment Recovery Activities

A. Mesa Trailer Park Survey

Initial survey teams Nos. 1 and 2 departed the FCP at 1045 hours. Team No. 1 arrived at the trailer park at 1115 hours, having obtained only background radiation readings. Team No. 2 reached the trailer park at 1120 hours and also obtained only background measurements. While performing a survey at the muck pile near the U12e portal, the maximum radiation reading of 0.08 mR/h was obtained. At 1200 hours, Mesa experiment recovery teams were permitted to enter the area. They performed their tasks and exited the area at 1300 hours. All remaining personnel departed the Mesa at 1415 hours.

B. Portal Survey

Radsafe survey teams Nos. 3 and 4 departed the FCP at 1245, completing their survey at 1310 hours after obtaining only background radiation readings. An afternoon reentry to the portal area was made to obtain remote gas samples. Sampling was complete at 1430 hours. Results of samples taken from

1. the portal side of the gas seal door,
2. the zero point side of the gas seal door,
3. the portal side of the overburden plug, and
4. the U12e main drift vent line.

indicated only normal air after being analyzed using a gas chromatograph. Only a sample taken from the zero point side of the overburden plug at 1401 hours showed any toxic gas, with a concentration of 500 ppm carbon monoxide being detected.

Tunnel ventilation began at 1545 hours, and the Radsafe base station and associated equipment were moved to the portal area at 1635 hours.

No reentries beyond the portal were made on D-day.

4.4 POSTEVENT ACTIVITIES

4.4.1 Initial Tunnel Reentry

Because gas chromatograph sampling on 6 December at 0800 hours indicated that toxic gas concentrations were only trace amounts in the tunnel, and radiation levels in most tunnel areas were background, initial tunnel reentry team No. 1 personnel boarded the train and entered the U12e tunnel main drift at 0905 hours. Team members were dressed in anticontamination clothing and equipment. The tunnel was in good condition and the team arrived at the gas seal door at 0940 hours. After checking radiation, toxic gas, and explosive mixtures (with negative results) they opened and chained open the manway door in the gas seal door, and proceeded to the overburden plug. No radiological or toxic gas problems were encountered. The overburden plug door was prepared for opening, after which team No. 1 exited the tunnel at 1206 hours. No contamination was detected on their clothing.

Team No. 2 entered the tunnel at 1225 hours to repair a communications line at the overburden plug. Repairs were completed and they exited the tunnel at 1307 hours.

Teams Nos. 3 and 4 entered the tunnel at 1330 hours to finish opening the overburden plug door and remove sandbags, and attempt to improve communications before other tunnel entries were made. The overburden plug door was opened at 1345 hours. No water was on the tunnel floor and no radiation problems were encountered. Team No. 4 exited the tunnel at 1405 hours, and team No. 3 exited the tunnel at 1432 hours.

The scientific assessment team (team No. 5) entered the tunnel at 1500 hours and traveled to test chamber No. 1. No toxic gases or explosive mixtures were detected; however, the gamma radiation intensity at the door measured 34 mR/h. They continued toward the zero point, obtaining a reading of 600 ppm carbon monoxide at 1534 hours at a break in the LOS pipe. By 1610 hours, they had arrived at test chamber No. 2. The maximum gamma radiation detected at this location was 70 mR/h. The door to test chamber No. 2 was opened and radiation readings again were taken. In addition to a radiation reading of 70 mR/h, a measurement of 500 ppm carbon monoxide was obtained. The tunnel had collapsed between test chambers Nos. 2 and 3; however, access to test chamber No. 3 was gained by crawling on top of the LOS pipe. Team No. 5 exited the tunnel at 1640 hours. No alpha radiation was detected. The tunnel was secured at 1715 hours.

4.4.2 Experiment Recovery Operations

On 7 December, two reentry teams entered the tunnel. One team entered at 0835 hours, recovered magnetic tape, and exited the tunnel at 0920 hours. The second team entered the tunnel at 0952 and traveled to the overburden plug where they put on Scott-Draeger breathing units before continuing toward scientific station No. 2. The team entered the LOS pipe at test chamber No. 2, at 1130 hours, and began to walk-out the LOS pipe. The maximum radiation reading was 400 mR/h at the location of main experiments. No toxic gases or explosive mixtures were detected. After checking the TAPS, which appeared to have sealed properly, the team exited the tunnel at 1220 hours. Air Force Weapons Laboratory (AFWL), LMSC, SLA, and DASA personnel were underground performing recovery tasks from 1320 hours to 1500 hours. No anticontamination clothing was required from the portal to the overburden plug; beyond the overburden plug, full anticontamination clothing was required. By 1600 hours, all personnel had exited the tunnel and it was secured.

From 8 December 1969 to 16 January 1970, the major portions of experiment recoveries were conducted by personnel representing SLA, DASA, LMSC, General Electric (GE), LRL, LASL, GA, U.S. Geological Survey (USGS), and Space and Missile Systems Organization (SAMSO). No radiation problems were encountered. A maximum toxic gas concentration of 18,000 ppm carbon monoxide was measured around the TAPS seal on 9 December. The explosive mixture maximum reading of 20 percent LEL was measured at this same location during the same survey. The maximum concentration of carbon monoxide to which personnel inside the LOS pipe were exposed was

75 ppm. Toxic gas problems were remedied by increasing ventilation and removing personnel from the area until concentrations decreased.

From 17 January to 6 March, reentry activities included additional experiment recoveries from the SLA and LASL alcoves and inspection and removal of selected experiment protection devices.

4.4.3 Industrial Safety

Toxic gases and explosive mixtures were continuously monitored and recorded in the monitors' log book. Maximum readings in the tunnel complex were 18,000 ppm carbon monoxide at the TAPS on 9 December at 1610 hours; 20% LEL of explosive mixtures on the same day and at the same location; and only traces of $NO+NO_2$ at various times and dates during recovery operations.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes, including specific codes for mining and drilling were established by REECo and emphasized during all operations. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive material, or any other operation with the potential for personal injury. Each individual involved in the project was required to be knowledgeable of the contents of these procedures.

The portal construction area and the tunnel were hard hat and foot protection areas. Each participating agency provided its own industrial safety apparel. All personnel on the initial tunnel reentry teams were certified in the use of the McCaa 2-hour breathing apparatus and had used the Scott-Draeger self-contained breathing apparatus. Standard safety rules and practices, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

All explosives, electro-explosive components, solid propellants, toxic material, and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224)
2. AEC Manual 500 Series for the Nevada Test Site
3. Individual Safe Operating Procedures (by experimenter organizations)
4. DIESEL TRAIN Safety Regulations

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DOD Safety Coordinator.

4.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 0901 hours on 5 December 1969. The maximum gamma intensity detected was 350 R/h at 0901 hours on 5 December at telemetry station No. 31, located 156 feet inside of the U12e.11 drift.

The initial surface reentry survey into the area began at 1045 hours and ended at 1415 hours on 5 December 1969, after initial recoveries had been made. The maximum exposure rate was 0.08 mR/h at the muck pile near the U12e portal. No alpha radiation was detected.

The initial tunnel reentry began at 0905 hours on 6 December and was completed at 1206 hours. The maximum radiation reading of 400 mR/h was obtained at 1130 hours during a walk-out of the LOS pipe on 7 December. No alpha radiation was detected during reentries on 6 and 7 December.

The maximum concentrations of toxic gases and explosive mixtures measured during the entire operation were 18,000 ppm carbon monoxide and 20 percent LEL, respectively. These concentrations were detected during a survey conducted on 9 December 1969 at the TAPS.

Personnel exposures received during individual entries to DIESEL TRAIN radex areas from 5 December 1969 to 6 March 1970 are summarized below. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers. Maximum exposures are from film dosimeter records.

	No. of Entries Logged	Maximum Exposure ~~(mR/h)~~ (mR)	Average Exposure ~~(mR/h)~~ (mR)
All Participants	1,253	85	1
DOD Participants	384	125	1

CHAPTER 5

DIANA MIST EVENT

5.1 EVENT SUMMARY

The DIANA MIST event was conducted at 1115 hours PST on 11 February 1970, with a device yield less than 20 kt. Emplacement of the LASL-provided device was at a vertical depth of 1,319 feet in tunnel U12n.06 (Figures 20 and 21). Government agencies and contractors participated in 18 projects as a part of this event, which was a weapons effects test to study the response of equipment and materials to a nuclear detonation environment. DIANA MIST was a successfully contained event.

5.2 PREEVENT ACTIVITIES

5.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all DIANA MIST event activities in Area 12, subject to controls and procedures established by the Test Manager and the NTSO. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Test Command, DASA, and the AEC Nevada Operations Office.

Project agencies were responsible for designing, preparing, and installing their experiments, or delivering them to an installation contractor for subsequent placement. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

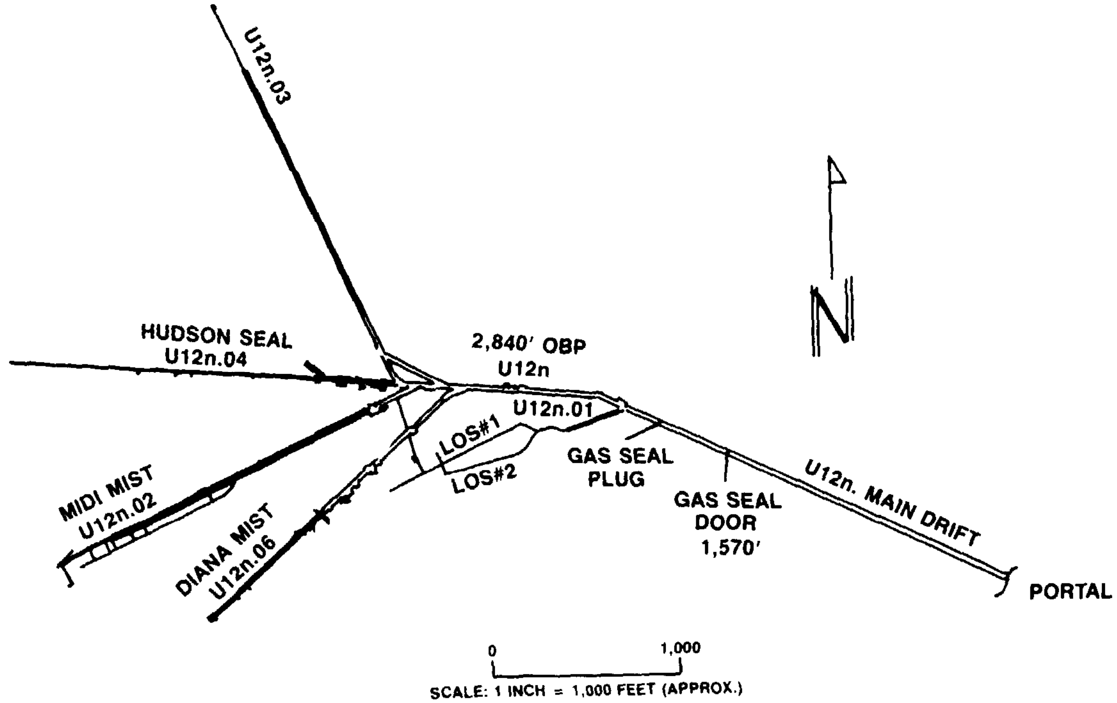

Figure 20. DIANA MIST Event tunnel layout.

Because LASL fielded the device, the LASL Test Group Director was responsible for radiological safety within a 5,000-foot radius of SGZ. This responsibility was in effect from device emplacement until device detonation. At that time, the Test Manager relieved the LASL Test Group Director of responsibility and delegated responsibility to the DOD Test Group Director. Device safety and security procedures in the GZ area and the timing and firing control room were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

5.2.2 Planning and Preparations

A. Tunnel Facilities Construction

Mining of the U12n.06 drift began in February 1969. Access to the DIANA MIST drift via the U12n main drift required passage through the remains of the HUDSON SEAL overburden plug located 2,840 feet from the portal. Six alcoves were mined in both sides of the test drift; four on the right rib for test chamber access and two on the left for vacuum pumping equipment. Installation of the LOS pipe began on 5 September 1969 with subsequent installation of internal experiments conducted between 10 December 1969 and 4 February 1970. External experiment installation began on 16 December 1969 and was finished on 24 January 1970. Instrumentation trailers were installed and shock-mounted during November and December.

B. Radiological Safety Support

Procedures for radiation exposure and contamination control during this event were in accordance with requirements of responsible DOD and SLA representatives. Radsafe provided monitoring and equipment support, air sampling, and telemetry.

Detailed radiological safety reentry plans ("DIANA MIST Reentry Plan") were prepared and issued to participating agencies for implementation prior to the test. Reference markers and air sampling equipment were positioned in the test area. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial surface radiation surveys, perform aerial surveys by helicopter, and participate in reentry parties, as needed. Radsafe personnel also were standing by at the FCP prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support

Forty-four RAMS units provided surface and underground coverage for the DIANA MIST event as described in Table 6 and shown in Figure 21.

One portal air sampling unit (M-102) was positioned at the U12n portal and activated prior to zero time.

PHS personnel operated 103 air sampling stations and 29 gamma rate recorder stations in the offsite area. Twenty-four personnel were fielded for offsite surveillance.

Table 6. DIANA MIST Event RAMS unit locations.

Station	Location
	SURFACE
1	Portal
2	530 feet at 330° azimuth from the portal
3	530 feet at 330° azimuth from the portal (No. 1 vent line)
4	530 feet at 330° azimuth from the portal (No. 2 vent line)
6	400 feet at 16° azimuth from the portal
7	275 feet at 89° azimuth from the portal
8	363 feet at 164° azimuth from the portal
9	482 feet at 192° azimuth from the portal
10	558 feet at 192° azimuth from the portal
11	416 feet at 192° azimuth from the portal
12	648 feet at 192° azimuth from the portal
13	1,316 feet at 192° azimuth from the portal
14	1,368 feet at 192° azimuth from the portal
15	2,773 feet at 192° azimuth from the portal
16	2,776 feet at 192° azimuth from the portal
17	3,086 feet at 192° azimuth from the portal
18	3,110 feet at the downhole building from the portal on the vent line
19	3,350 feet at 192° azimuth from the portal
20	3,240 feet at the downhole building from the portal
21	3,130 feet at 192° azimuth from the portal
22	3,300 feet at 192° azimuth from the portal
23	3,490 feet at 192° azimuth from the portal
24	500 feet at 0° azimuth from SGZ
25	500 feet at 115° azimuth from SGZ

Table 6. (Concluded)

Station	Location
	SURFACE (Concluded)
26	500 feet at 240° azimuth from SGZ
	UNDERGROUND
29	85 feet into the 04 drift
30	1,025 feet into the 06 drift
31	886 feet into the 06 drift
32	675 feet into the 06 drift
32AT*	640 feet into the 06 drift
33	422 feet into the 06 drift
34	500 feet into the 02 drift
35	141 feet into the 02 drift
36	3,002 feet into the main drift
36AT*	3,023 feet into the main drift
37	2,546 feet into the main drift
38	300 feet into the 01 drift
39	50 feet into the 01 drift
40	1,700 feet into the main drift
40AT*	1,617 feet into the main drift
41	1,475 feet into the main drift
42	900 feet into the main drift
43	50 feet into the main drift at the vent line
44	200 feet into the main drift

*Buried

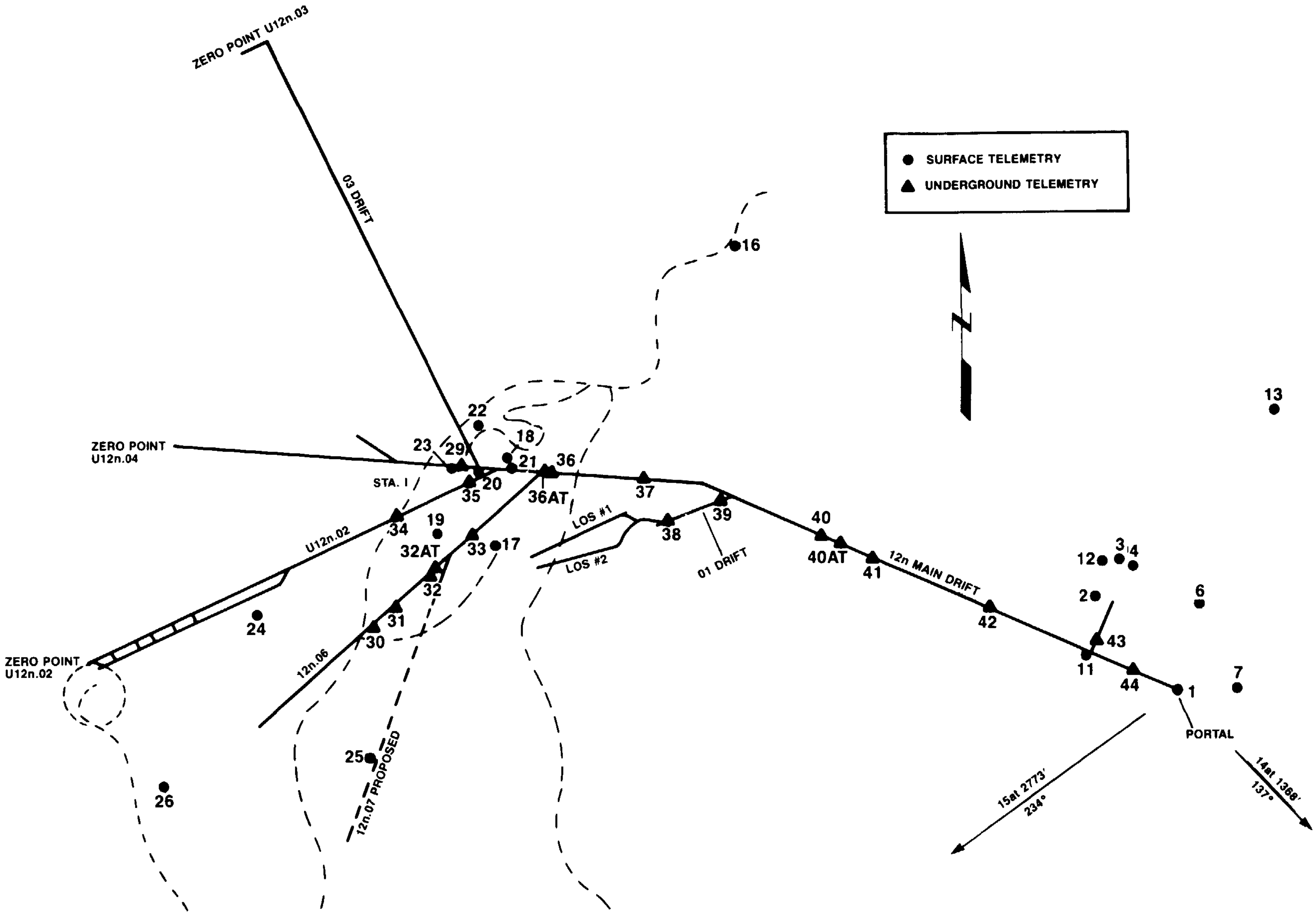

Figure 21. DIANA MIST Event surface and underground RAMS unit locations.

D. Security Coverage

Device security procedures in the zero point area and the timing and firing control room were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." All personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges, or issue and return of muster badges. After area control was established, all through traffic was diverted around the controlled area by use of screening stations.

In accordance with the "Test Manager's Operations Plan," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

E. Air Support

One UH-1F helicopter with USAF crew performed preevent security sweeps and then was used for DOD event photography. An additional UH-1F with USAF crew was used for aerial closed circuit television coverage. The USAF provided a U-3B and crew to support PHS personnel for cloud tracking, a Turbo Beech for cloud sampling, and a Turbo Beech on standby at McCarran Airport in Las Vegas for additional cloud sampling support, if needed. The EG&G/NATS aircraft, a Martin 404, also was on standby at McCarran Airport in Las Vegas.

5.2.3 Late Preevent Activities

On 5 February, the event was rescheduled from 10 to 11 February to reduce pressure on experimenters making final preparations and to allow more time for button up.

Button up activities were performed by personnel representing SLA, LASL, EG&G, Physics International (PI), Philco-Ford, Lockheed Palo Alto Research Laboratory (LPARL), LMSC, AVCO Corporation (AVCO), AFWL, and GA, and a successful dry run was completed on 10 February. A readiness briefing followed at 1430 hours. At that meeting, a tentative zero time of 0900 hours on 11 February was selected. Between 2100 and 2210 hours, roadblocks were established and the first security sweep was conducted.

5.3 EVENT-DAY AND CONTINUING ACTIVITIES

After several security sweeps had been conducted, the closed area was declared clear for arming at 0519 hours. Permission to arm was granted at 0525 and by 0555 hours the device was armed. At 0805 hours, test execution was put on indefinite hold due to technical problems. These were subsequently resolved and a new detonation time of 1115 hours was scheduled.

DIANA MIST zero time was 1115 hours PST on 11 February 1970.

5.3.1 Test Area Monitoring

Telemetry measurements began at 1116 hours on 11 February 1970. The maximum gamma reading obtained was 400 R/h at RAMS unit No. 31 (underground) at 1116 hours on 11 February. With the exception of RAMS unit No. 26, surface units showed background radiation levels from zero time plus one minute until they were secured. Unit No. 26 increased from background at 1116 hours to a maximum of 6 mR/h at 1121 hours; then steadily decreased to background again at 1140 hours. This unit was visually checked during initial surface reentry by Radsafe monitors who found that the cable had been smashed by a falling rock. The location was surveyed with hand-held radiation detection instruments, and no readings above background were detected. RAMS unit No. 26 continued to indicate background readings until it was secured at 1615 hours on 11 February. All underground units which originally measured radiation levels above background showed continuous decreases until they were secured. RAMS unit Nos. 12 through 25 were secured at 0720 hours on 12 February; Nos. 36AT, 37, 39, 40AT, and 42 were secured at 0745 hours that same day; the remaining units were secured at 1315 hours on 13 February.

5.3.2 Initial Surface Radiation Surveys and Experiment Recovery Activities

Initial surface radiation survey teams Nos. 1 and 2 were released to survey Rainier Mesa trailer park at 1210 hours on D-day. In addition to their normal duties, team No. 1 checked RAMS unit No. 26 which had shown an unexplained increase in readings (see 5.3.1), and confirmed that the unit was non-operational. The Mesa survey was completed at 1242 hours, and all radiation readings were background for that area. Initial experiment recovery teams were authorized into the Mesa trailer park at 1310 hours. At 1328 hours, while recovery operations were in progress on the Mesa, initial portal survey teams (Nos. 3 and 4) were authorized to proceed with their surveys. Initial portal surveys were completed at 1500 hours with no radiation readings above background being detected. Recovery operations continued until 1735 hours when all initial survey teams and experiment recovery parties exited the controlled area. No tunnel reentries or experiment recoveries were conducted on D-day.

After event detonation, air sampling lines, connected to a valve system and vacuum pump which had been installed preevent, were used to draw air from selected locations. This procedure was performed remotely (starting at 1604 hours) by means of a control panel located outside the portal near a trailer housing a gas chromatograph. After air samples were collected, the gas chromatograph was used to analyze them for the presence of toxic and explosive gases. Results of these analyses were one of the factors used to determine when initial tunnel reentry operations could safely begin. Analyses results for DIANA MIST indicated that maximum gas concentrations detected inside the tunnel were 5 percent hydrogen and 0.8 percent carbon monoxide. Because the hydrogen concentration was above the LEL, ventilation of the tunnel complex was required, and it was authorized to begin at 1704 hours on D-day.

At 1930 hours, Radsafe personnel began moving the base station to the portal area and preparing for a planned tunnel reentry on D+1 if tunnel ventilation was successful.

5.4 POSTEVENT ACTIVITIES

5.4.1 Tunnel Reentry and Experiment Recovery Activities

At 0800 hours on 12 February, results obtained from additional gas chromatograph samples indicated that no toxic gases or explosive mixtures were currently present in the tunnel atmosphere. After evaluating all pertinent factors, the decision was made to begin initial tunnel reentry operations. Members of initial tunnel reentry team No. 1 donned anticontamination clothing, boarded the man-train, and entered the tunnel at 0945 hours. They encountered no tunnel damage other than very minor rock spalling as they traveled toward the gas seal door. Respiratory protection equipment was put on when they reached the gas seal door as a precautionary measure during the opening of the small manway door. However, it turned out that no toxic gases, explosive mixtures, or radiation problems were encountered during the performance of this task. After the small manway door was opened, conditions were judged to be favorable for opening the large gas seal door. This effort was completed by 1048 hours.

At 1115 hours, the team left the gas seal door and continued on into the tunnel, checking the 02, 03, and 04 drifts before returning to the U12n.06 drift. All areas checked were found to be in good condition.

Team members began to walk-out the 06 drift at 1202 hours. After checking both vent lines and finding them to be in good condition, they continued into the drift observing only minor spalling along the way until they reached the overburden plug face at 1208 hours (Figure 22). Radiation levels at the overburden plug were monitored and found to be background. After performing preliminary work which would assist a subsequent reentry team in opening the overburden plug door, team No. 1 exited the tunnel at 1255 hours.

Team No. 2 entered the tunnel at 1325 hours on 12 February and traveled to the overburden plug where they began removing the final bolts from the overburden plug door. All team members were wearing Scott-Draeger self-contained breathing units and anti-contamination clothing. By 1400 hours, the door was opened and team members began removing sandbags to permit access farther into the drift. No toxic gases or explosive mixtures were detected and radiation levels were background at the overburden plug. When sufficient sandbags had been removed to allow access, team members continued into the drift, again observing only minor spalling as they traveled. Radiation levels increased from 0.03 mR/h to 0.3 mR/h just beyond the sandbag plug. The decision was made to travel no farther and team No. 2 exited the tunnel at 1425 hours.

Team No. 3, along with a rescue team (all dressed in anti-contamination clothing for reentry), entered the tunnel at 1452 hours and proceeded to the overburden plug where they established a fresh air station and established communications. At 1500 hours, team No. 3 passed through the overburden plug and pro-

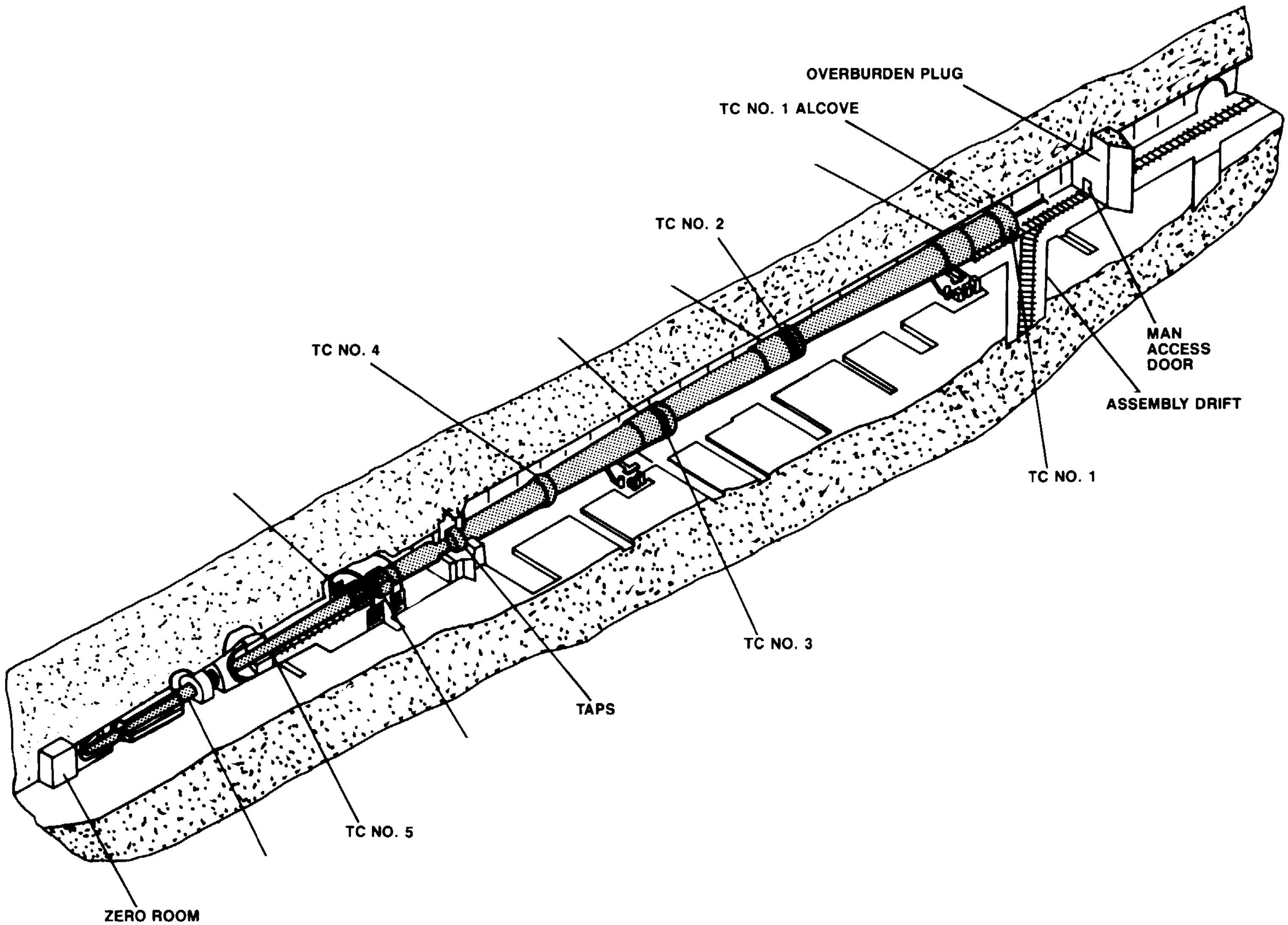

Figure 22. DIANA MIST Event LOS pipe layout.

ceeded to walk-out the exterior of the LOS pipe and inspect test chamber Nos. 2, 3, and 4 (Figure 22). Upon reaching test chamber No. 4, they noted some spalling and the concrete floor was badly broken. The team exited the area at 1549 hours and no other reentry activities were conducted on 12 February. The maximum reading detected at test chamber Nos. 1, 3, and 4 was 150 mR/h during this survey.

On 13 February at 0815 hours, team No. 3 and a rescue team began suiting up for tunnel reentry. Both teams entered the tunnel complex at 0930 hours, but the rescue team remained at the overburden plug. Reentry team No. 3 departed the overburden plug at 0946 hours, wearing full anticontamination clothing and Scott-Draeger self-contained breathing apparatus, and proceeded to inspect the LOS pipe drift. Gas chromatograph analysis had indicated 5,000 ppm methane and 9,500 ppm ethane inside the LOS pipe at 0920 hours. Since the 06 drift had previously been determined to be in good condition, team members traveled to test chamber No. 4 first, and worked their way back out of the drift, checking each individual test chamber as they progressed. They reached test chamber No. 4 at 1002 hours and began checking for radioactivity, toxic gases, and explosive mixtures. A reading greater than 3,000 ppm carbon monoxide was detected at the top outside of the door. When the door was opened, readings of 30 percent LEL of explosive mixtures and 70 mR/h were obtained. Team members connected the vent line into this test chamber in an effort to facilitate experiment recovery operations before advancing to test chamber No. 3 at 1028 hours. Test chamber No. 3 door was opened so samples could be taken. No explosive mixtures were detected, and a measurement of 600-700 ppm carbon monoxide was obtained at the back of the door. The team next checked test chamber No. 2. A measurement of 100 ppm carbon monoxide was obtained and no explosive mixtures were detected. By 1056 hours, the team had reached test chamber No. 1 where they obtained readings of 100 ppm carbon monoxide and 2 percent LEL of explosive mixtures. They continued toward the portal passing through the overburden plug at 1106 hours.

After team No. 3 exited the tunnel, teams were allowed to enter and prepare for pipe ventilation. A limited amount of experiment recovery work was performed in test chamber No. 3 during this time. The team exited the tunnel at 1503 hours and no further reentries or recovery operations were performed on 13, 14, or 15 February.

A walk-out of the LOS pipe was performed on 16 February beginning at approximately 1025 hours and ending at 1124 hours. Readings obtained were as follows:

Test Chamber No. 1:	No explosive mixtures No carbon monoxide 7 mR/h
Test Chamber No. 2:	Trace explosive mixtures No carbon monoxide 4 mR/h
Test Chamber No. 3:	No explosive mixtures No carbon monoxide 5 mR/h
Test Chamber No. 4:	No explosive mixtures No carbon monoxide 3 mR/h

Because it had a larger area for neutron activation than each of the other three test chambers, readings were slightly higher at test chamber no. 1, even though it was a greater distance from the zero point than the other chambers. After performing this survey, team members exited the tunnel at 1240 hours.

Anticontamination clothing and respiratory protection equipment requirements were suspended for areas outside the LOS pipe, except when recovery items were being handled. Requirements inside the pipe called for wearing a single anticontamination suit with an Acme full-face mask. The radex area was moved so that it began at the 06 drift instead of the portal.

Major experiment recovery operations were conducted between 17 and 20 February. Additional recovery entries continued until 2 March, and other entries continued until 18 March 1970. No radiation, toxic gas, or explosive mixture problems were experienced during recovery operations.

5.4.2 Postevent Drilling

Postevent drilling operations were not performed until 16 November 1973, when drilling into the U12n.06 chimney and cavity began. The objectives were to

A. evaluate the characteristics of the tuff surrounding and within 200 feet of the DIANA MIST cavity and chimney,

B. evaluate the permeability and porosity of the collapsed tuff within the DIANA MIST chimney,

C. obtain data points for estimating the size and shape of the DIANA MIST chimney, and

D. evaluate the competency of the tuff above the DIANA MIST chimney.

Fifty-one core samples were obtained during operations conducted from 19 to 29 November 1973. No radiation readings above background levels were measured on the core samples or in the drill rig area. Operations were completed on 7 December 1973.

5.4.3 Industrial Safety

The portal construction area and the tunnel were hard hat and foot protection areas (safety shoes, safety boots, miner's boots, or toe guards). Each participating agency provided its own safety equipment. All personnel on the initial tunnel reentry teams were certified in the use of the McCaa 2-hour breathing apparatus and had used the Scott-Draeger self-contained breathing apparatus. Standard safety rules and regulations, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

Checks were made on each shift for toxic gases and explosive mixtures. These measurements were recorded in the Radsafe monitors' log book. Industrial safety codes, including specific codes for mining and drilling were established by REECo and emphasized during all operations.

All explosives, electro-explosive components, solid propellants, toxic material, and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224)
2. AEC Manual 500 Series for the Nevada Test Site
3. Individual Safe Operating Procedures (by experimenter organization)
4. DIANA MIST Safety Regulations

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DOD Safety Coordinator. A written standard operating procedure was required for each operation involving explosives, toxic material, or any other operation with the potential for personal injury. Each individual involved in the project was required to be knowledgeable of the contents of this procedure.

5.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1116 hours on 11 February 1970. The maximum gamma exposure rate was 400 R/h at RAMS unit No. 31, located 886 feet inside the U12n.06 drift at 1116 hours on 11 February 1970. Telemetry station No. 26 (located 500 feet from SGZ) went off-line at 1146 hours on 11 February 1970 (see 5.3.1 for explanation). Remaining surface telemetry stations reported no radiation above background for DIANA MIST. All telemetry was discontinued at 1315 hours on 13 February.

Initial surface radiation surveys on Rainier Mesa were conducted between 1210 and 1242 hours on D-day. Portal surveys were conducted between 1335 and 1500 hours on D-day. No readings above background levels were detected during these surveys.

Initial tunnel surveys were conducted on D+1. The maximum reading obtained was 0.3 mR/h just beyond the overburden plug. A walkout of the outside of the LOS pipe conducted between 1452 and 1549 hours on D+1 produced a maximum reading of 150 mR/h at test chambers Nos. 1, 3, and 4.

The maximum concentration of hydrogen gas detected by gas chromatograph was five percent by volume in the LOS pipe at 1604 hours on 11 February 1970. This was greater than 100 percent of the LEL for hydrogen gas in standard air. The maximum concentration of toxic gases was 20,000 ppm carbon monoxide at test chamber No. 4 at 1530 hours on 12 February.

Experiment recovery operations ended successfully on 2 March 1970. There were no whole body external or internal organ exposures which exceeded the established guides.

Personnel exposures received during individual entries to the DIANA MIST event from 11 February 1970 to 18 March 1970 are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	417	70	1
DOD Participants	178	0*	0

*Minimum detectable gamma exposure with NTS film dosimeter is 30 mR per film packet worn.

CHAPTER 6

MINT LEAF EVENT

6.1 EVENT SUMMARY

The MINT LEAF device was detonated at 0830 hours PDT on 5 May 1970 with a yield less than 20 kt. LRL provided the device which was emplaced in tunnel U12t.01 at a vertical depth of 1,330 feet (Figure 23). The purpose of this test was to obtain weapons effects information by exposing equipment and materials to a nuclear detonation environment. Government agencies, weapons laboratories, and DOD contractors conducted 25 projects to obtain the desired information. Containment was normal until 34 minutes after the detonation when seepage of gaseous radioactive material from the end of stemming toward the portal began. This seepage continued until the cavity collapsed 62 hours and 14 minutes after the detonation. Minor levels of radioactive effluent were detected offsite after the MINT LEAF event.

6.2 PREEVENT ACTIVITIES

6.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all MINT LEAF event activities in Area 12, subject to controls and procedures established by the Test Manager and NTSO. AEC and AEC contractor responsibilities were in accordance with established AEC/DOD agreements or were the subject of separate action between Test Command, DASA, and the AEC Nevada Operations Office. Reentry and recovery programs were conducted by Sandia Laboratories, Albuquerque.

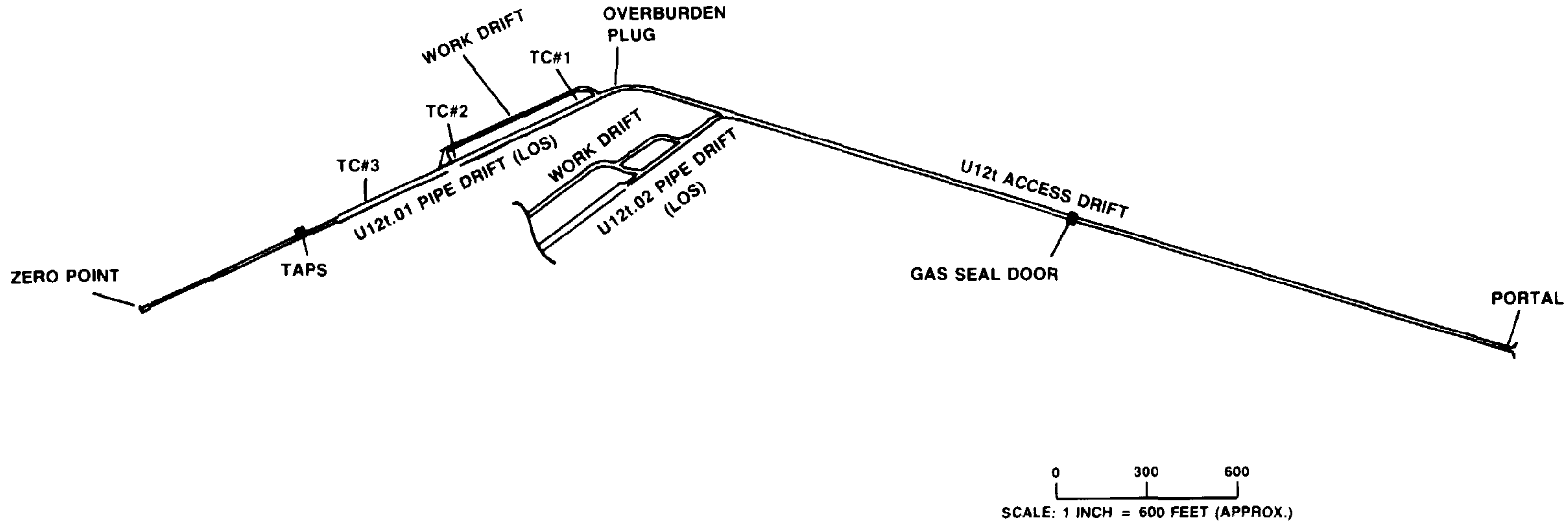

Figure 23. MINT LEAF Event tunnel layout.

The LRL Test Group Director was responsible to the Test Manager for radiological safety within a 6,000-foot radius of GZ. This responsibility was in effect from the time the device was moved to the zero point until device detonation. After device detonation, the Test Manager relieved the LRL Test Group Director of responsibility and delegated it to the DOD Test Group Director.

Lockheed Missile and Space Corporation was contracted to provide design, fabrication, and operation of the MINT LEAF experiment test bed facility and for technical monitoring of facility installation.

Project agencies were responsible for designing, preparing, and installing their experiments, or delivering them to an installation contractor for subsequent placement. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

6.2.2 Planning and Preparations

A. Radiological Safety Support

Radsafe personnel were stationed at the DOD Test Group Director's reentry staging area to perform emergency rescue and provide radiological support; provide anticontamination equipment, portable radiation sensing instruments, and dosimetric devices; provide personnel, vehicle, and equipment decontamination; operate sample collection stations; and provide laboratory counting facilities.

In the event of any emergency situation, Radsafe personnel who were stationed at the Mesa reentry and portal reentry points would assist, as directed by the Test Group Director, in a controlled evacuation of personnel from the test area.

Radsafe provided a sufficient number of certified, U.S. Bureau of Mines rescue-qualified, radiation monitoring personnel to accompany each initial postevent reentry team, and stand by for the rescue team as directed by the Sandia health physicist. These monitors also would perform radiation surveys and obtain samples, as requested.

Prior to their attempting scientific experiment recoveries, scientific personnel were briefed regarding radiation intensities, contamination levels, tunnel atmosphere, anticontamination clothing and respiratory protection equipment requirements, and time-in-area limits imposed by radiation levels. Available anticontamination clothing and equipment included head covers, coveralls, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves and masking tape.

B. Telemetry and Air Sampling Support

Forty-five RAMS units provided surface and underground coverage for the MINT LEAF event as shown in Figures 24 and 25, and Table 7.

Two air samplers (M-102s) were placed as follows:

1 - U12t portal
1 - U12t splice shack

The Pagoda air sampling trailer was used to sample the

Table 7. MINT LEAF Event RAMS unit locations.

Station	Location
	SURFACE
1	Portal
2	On filter system
3	On filter system
4	On filter system
5	270 feet at 22°45' azimuth from portal
6	345 feet at 68°19' azimuth from portal
7	289 feet at 104°21' azimuth from portal
8	388 feet at 171°13' azimuth from portal
9	324 feet at 223°02' azimuth from portal
10	265 feet at 273°40' azimuth from portal
11	200 feet at 327°09' azimuth from portal
12	3,110 feet at 67°47' azimuth from portal
13	2,777 feet at 92°52' azimuth from portal
14	1,714 feet at 123°45' azimuth from portal
15	1,671 feet at 213°31' azimuth from portal
16	2,840 feet at 241°0' azimuth from portal
17	1,470 feet at 271°07' azimuth from portal
18	1,368 feet at 323°23' azimuth from portal
19	2,498 feet at 32°28' azimuth from portal
20	Between cable holes 1 and 2
21	242 feet at 6°20' azimuth from cable hole No. 1
22	487 feet at 71°25' azimuth from cable hole No. 1
23	169 feet at 186°0' azimuth from cable hole No. 1

Table 7. (Concluded)

Station	Location
	SURFACE (Concluded)
24	168 feet at 271°30' azimuth from cable hole No. 1
25	680 feet at 169°53' azimuth from SGZ
26	1,671 feet at 316°18' azimuth from SGZ
27	831 feet at 35°45' azimuth from SGZ
	UNDERGROUND
28	300 feet into the 02 work drift
29	700 feet into the 02 drift
30AT*	1,190 feet into the 01 drift
31	820 feet into the 01 drift
32	650 feet into the 01 work drift
33	145 feet into the 01 work drift
34	311 feet into the 01 drift
35	165 feet into the 01 drift
36AT*	195 feet into the 01 drift
37	80 feet into the 01 drift
38	150 feet into the CA drift
39	3,085 feet into the main drift
40	2,500 feet into the main drift
41	1,770 feet into the main drift
42AT*	1,770 feet into the main drift
43	1,670 feet into the main drift
44	900 feet into the main drift
45	100 feet into the main drift

*Buried

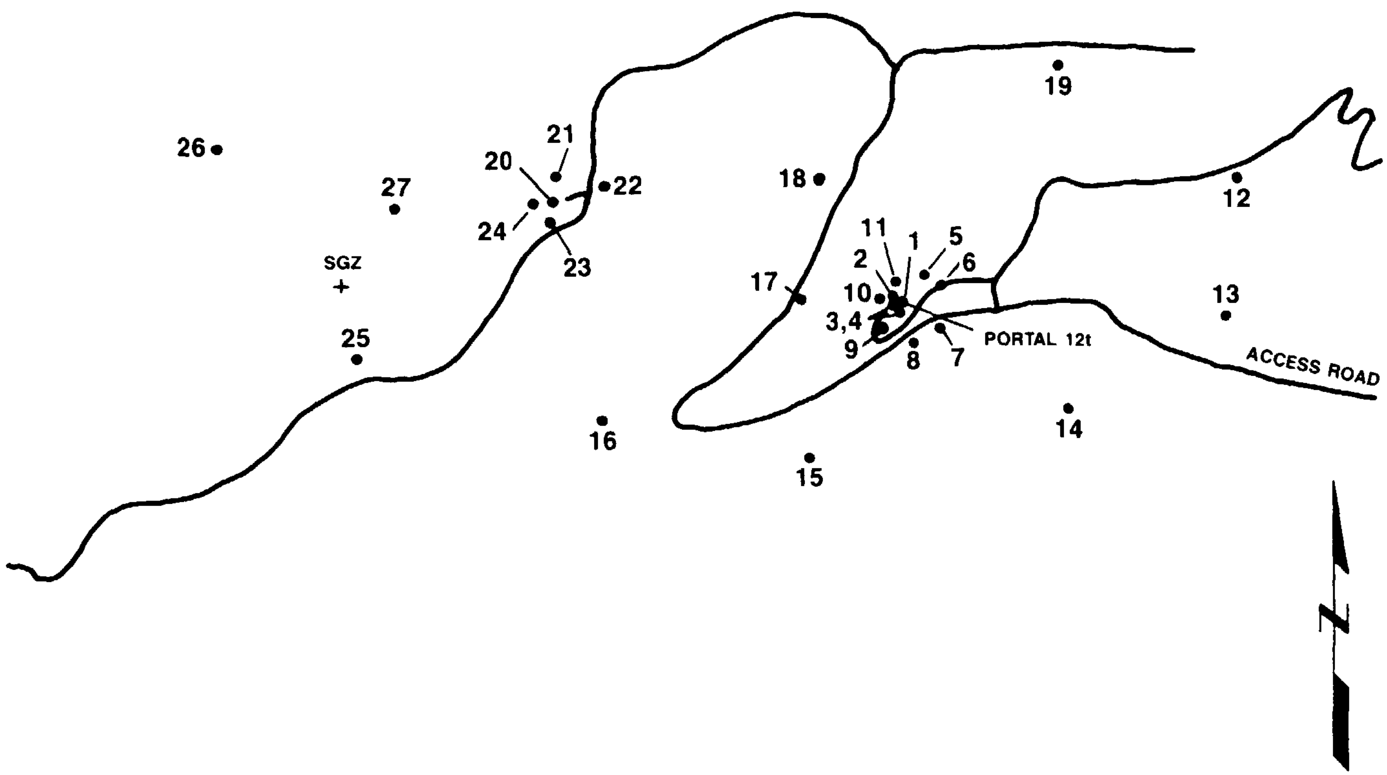

Figure 24. MINT LEAF Event surface RAMS unit locations.

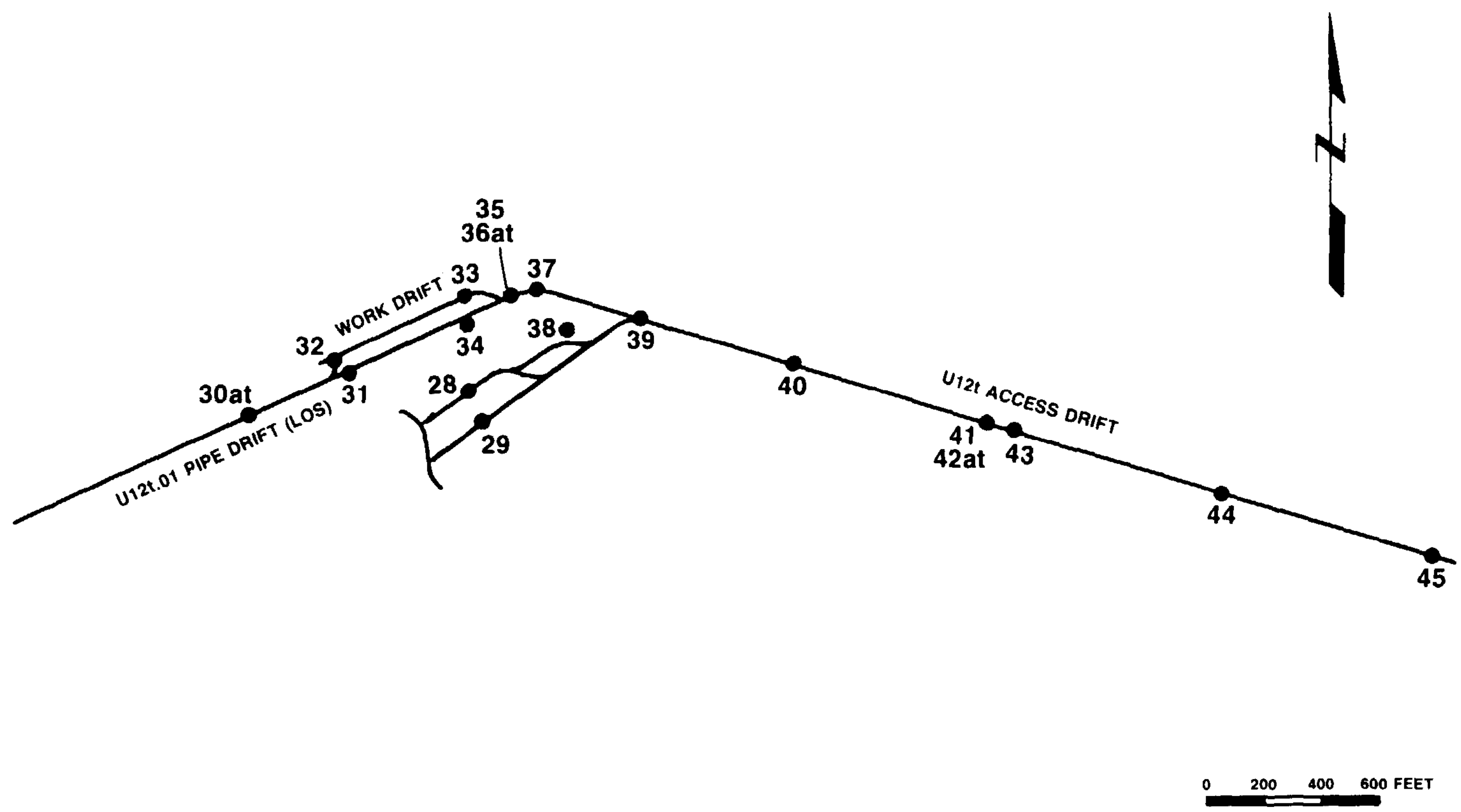

Figure 25. MINT LEAF Event underground RAMS unit locations.

vent lines. Four heads were used, with two samplers before the filter boxes and two after the filter boxes. All of the cartridges used were of the standard activated charcoal type.

Detectors of a multi-channel geophone system were installed in the tunnel to monitor postevent seismic disturbances.

The PHS operated 101 air sampling stations and 32 gamma rate recorder stations in the offsite area. Twenty-two personnel were fielded for offsite surveillance activities.

C. Security Coverage

Specific security procedures for the MINT LEAF event were delineated in "MINT LEAF-01 5200.16, Security Operating Instructions." Device security procedures in the zero point area and the timing and firing control room were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

All personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges, or issue and return of muster badges. After area control was established, all through traffic was diverted around the controlled area by use of screening stations.

In accordance with the "Test Manager's Operations Plan," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

D. Air Support

One UH-1F helicopter with USAF crew performed preevent security sweeps and then was put on standby for the Test Manager's use if needed. An additional UH-1F helicopter with USAF crew was used for DOD aerial photography. A USAF U-3B aircraft with USAF crew and PHS monitoring personnel on board was used for cloud tracking. The PHS used one Turbo Beech aircraft for cloud sampling, while one PHS Turbo Beech remained on standby at McCarran Airport in Las Vegas. The NATS Martin 404 aircraft also was on standby at McCarran Airport to be used for cloud tracking purposes if needed.

6.2.3 Late Preevent Activities

Final inspection and button up activities were performed on 23 April in anticipation of scheduled test execution on 28 April. Button up activities were performed by personnel representing SLA, Bendix Corporation, EG&G, LMSC, PI, Effects Technology Inc. (ETI), Bell Telephone Laboratories (BTL), McDonnell Douglas Aircraft Corp. (MDAC), Stanford Research Institute (SRI), LRL, GA, and MIT. Preevent readiness briefings were held on 27 April and 30 April; however, unfavorable weather conditions prevailed and the event finally was scheduled for 5 May 1970 at 0730 hours. A readiness briefing was held at 1430 hours on 4 May, at which time weather conditions were favorable.

The first security sweep of the closed area was performed between 1945 and 2200 hours on 4 May, and the second sweep began at 2225 hours.

6.3 EVENT-DAY AND CONTINUING ACTIVITIES

The second security sweep was completed at 0020 hours on

D-day. At 0230 hours, the arming party entered the area. A readiness briefing was held at 0400 hours. Because weather conditions remained favorable, permission to arm the device was granted at 0442 hours. At 0640 hours, a one-hour hold was called and zero time was rescheduled for 0830.

MINT LEAF was detonated at 0830 hours PDT on 5 May 1970.

6.3.1 Test Area Monitoring

Telemetry measurements began at 0831 hours. Four RAMS units in the surface array were lost at zero time. All other units functioned properly.

RAMS units located in the LOS drift (Nos. 30AT, 31, 34, 35, and 36AT) indicated zero time activation of the test chambers as expected. These readings decreased exponentially with time until H+34 minutes when units on the zero point side of the overburden plug began to show increases which were attributed to gas leakage. Temperatures and pressures in the tunnel were closely monitored. The lack of change in the temperature and pressure indicated the gas leakage volume was small compared to test drift volume.

At H+2 hours, some radioactivity was measured in the cable alcove on the portal side of the overburden plug, but still on the zero point side of the gas seal door located in the main drift.

Remote sampling of the radioactive gases on the zero point side of the overburden plug began at approximately 1305 hours. Release of these gases to the atmosphere was controlled through a ventilation filter system which consisted of a prefilter, filter, and one-half ton of activated charcoal. RAMS unit Nos. 2, 3, and 4, located at the ventilation filters, detected levels ranging from zero at 1300 hours to a maximum of 750 mR/h at 1335 hours. The maximum telemetry measurement was 700 R/h at 1320 hours on D-day at unit No. 31 located 820 feet from the zero point. Radioactive effluent not retained by the filters consisted primarily of xenon-135 and about one percent of the activity was krypton-85m. At this point, the decision was made to delay tunnel ventilation until D+1.

A controlled venting through the filter system began at 0830 hours on 6 May (D+1). Since the winds were very favorable, tunnel ventilation was carried out during most of the day, but was discontinued at 1530 hours PDT because there was reason to believe the winds would soon shift to an unfavorable direction. The maximum reading measured during this controlled release was 35 R/h at unit No. 2 at 1130 hours. Readings on the portal side of the overburden plug peaked at 22 R/h at approximately 0930 hours (H+25 hours). The maximum reading on the zero point side of the gas seal door was 3.2 R/h at the same time.

The decay of radiation in the LOS drift, even after this initial ventilation effort, did not consistently follow a gross fission product decay curve, indicating that the seepage of radioactive material was continuing. Late on 7 May (D+2), a strong indication of cavity collapse was detected by the geophones. After collapse, radiation levels in the tunnel followed the expected decay curve.

The ventilation system was turned on for a third time at 0647 hours on 12 May (D+7). Documentation of the radioactive effluent continued until radiation levels measured by RAMS unit Nos. 2, 3, and 4, located on the vent lines, indicated essentially background. The maximum reading of 500 mR/h was detected by unit No. 2 at 1515 hours. Continuous samples of the effluent indicated that less than one curie of radioactive iodine was released to the atmosphere.

All telemetry was secured at 1115 hours on 2 June 1970.

6.3.2 Initial Surface Radiation Surveys and Experiment Recovery Activities

Radsafe survey teams Nos. 3 and 4 were released to survey the Holmes Road and Mesa trailer park at 0930 hours on D-day. This survey was completed at 1130 hours and monitors obtained only background readings. No alpha radiation was detected. At 0937 hours, the trailer park recovery teams and cable disconnect team were released from the Test Manager's Barricade, reaching the trailer park at 1010 hours. Recovery operations at the trailer park were completed at 1100 hours.

Radsafe survey teams Nos. 1 and 2 were released to survey the East Mesa Road and the U12t tunnel portal at 0935 hours. This survey was completed at 1015 hours and all readings were background. No alpha radiation was detected. Initial portal recovery teams entered the portal trailer park at 0951 hours and recovery operations were completed at 1018 hours.

At 1212 hours, a Radsafe survey team accompanied the gas chromatograph sampling team into the portal area. Gas samples taken from the zero point side of the overburden plug read 1.5 mR/h. The exposure rate in the gas chromatograph trailer was 80 mR/h and at contact with the gas chromatograph line in the trailer it was 200 mR/h. Gas samples from outside of test chamber No. 3 indicated 3,400 ppm hydrogen, 600-1,000 ppm methane, and 250 ppm carbon monoxide. Gas chromatograph samples taken at 1340 hours from inside the overburden plug indicated 900 ppm hydrogen, 100 ppm methane, and 120 ppm carbon monoxide. The exposure rate in the gas chromatograph trailer had increased to 2 R/h and the team left the area. No further reentries were made on D-day.

6.3.3 Aerial Monitoring

The USAF U-3B aircraft began performing its tracking mission at 0838 hours on D-day. After repeated passes over SGZ with no readings above background detected, the mission was terminated at 0904 hours. The PHS Turbo Beech also was airborne for a short time on D-day. No readings above background were obtained, and no samples were taken.

The Turbo Beech aircraft was airborne again on D+1 day. Sampling was conducted between 1005 and 1055 hours.

At 1130 hours on D+1 day, at the request of the Test Manager, Vegas 5 (the NATS plane) began a cloud tracking operation. At 1235, the Vegas 5 crew reported that they were detecting only xenon-135. It was shown by the tracking information that the cloud had blown due north, and at 1400 hours the leading edge was 100 miles from the U12t portal. This was 5.5 hours after the initiation of tunnel ventilation.

6.4 POSTEVENT ACTIVITIES

6.4.1 Tunnel Reentry and Experiment Recovery Activities

Tunnel reentry began at 1015 hours on 13 May 1970 when team No. 1 entered the tunnel. All reentry and experiment recovery teams were dressed in anticontamination clothing and Scott-Draeger self-contained breathing apparatus. Team No. 1 exited the tunnel at 1140 hours. Team No. 2 entered the tunnel at 1155 hours, opened the gas seal door, and began reinstalling the railroad tracks. They exited the tunnel at 1245 hours. From 1325 hours to 1425 hours, team No. 3 entered the tunnel and completed reinstallation of the tracks. Team No. 4 performed the last reentry of the day. They entered the tunnel at 1445 hours, checked the containment assessment drift, and exited the tunnel at 1615 hours.

On 14 May, three reentries into the tunnel complex were performed. Team No. 1 entered at 0820 to install sump pumps at the overburden plug. This was accomplished, and the team exited the tunnel at 0940 hours. Team No. 2 performed its assigned tasks from 0955 to 1200 hours. Team No. 3 entered the tunnel at 1215 hours. Unexpectedly, the exposure rate at the overburden plug had increased from 200 mR/h at 1230 hours to 1 R/h at 1245 hours. Reentry personnel were immediately evacuated from the area. The increase was believed to be caused by contaminated water which was running along the railroad tracks. A pump was installed to remove some of the water and sandbags were brought in to contain the rest. Team No. 3 exited the tunnel at 1415 hours.

Five reentry teams were used on 15 May 1970. Their objective was to open the overburden plug door and check out the tunnel condition beyond that point. This was successfully accomplished between 0925 and 1600 hours. The maximum reading obtained was 1 R/h on the zero point side of the overburden plug. No toxic gases or explosive mixtures were detected.

Reentry parties checked test chamber Nos. 1, 2, and 3 between 0835 and 1555 hours on 18 May. Test chamber No. 1 was found to be in good condition with no structural damage. Test chamber No. 2 was in the same general condition except that there was water on the floor. Test chamber No. 3 had sand, rock, and sandbags on the floor. Approximately 50 feet beyond test chamber No. 3, an exposure rate of 5 R/h was encountered by team No. 2. Later, when team No. 2 was in the tunnel, they walked to within 30 feet of the TAPS where they encountered an exposure rate of 10 R/h. All reentry teams were dressed in anticontamination clothing and wore Scott-Draeger self-contained breathing apparatus.

From 19 May to 17 June 1970 experiment recovery activities were performed by personnel representing LRL, PI, DASA, LMSC, Kaman Nuclear (KN), EG&G, SLA, and AFWL.

On two later occasions, during routine operations, the presence of hydrogen sulfide was detected in the tunnel complex. The first occurrence was on 25 June when personnel reentered the tunnel and attempted to open the TAPS drain to draw water and air samples. When the plug was removed, a spout of water indicated that a larger amount of water probably existed behind the TAPS. Strong odors of hydrogen sulfide from the drain water were noticed. The hydrogen sulfide odor dissipated rather rapidly as the water was drained. The second occurrence was on 21 September 1970 at 0930 hours when a trace of hydrogen sulfide was detected in the drain sump just above the water's surface. A waist-high measurement however, indicated no presence of hydrogen sulfide. There was no further record of hydrogen sulfide being detected during this operation.

Little reentry work was performed between 1 July and 1 October 1970 due to a labor union dispute. Some work was accomplished using supervisory personnel. By mid-December, manpower levels were approaching normalcy. On 18 December, the DOE BANEBERRY test (in Area 8) vented, causing a shutdown of Area 12 until 1 February 1971. After some careful cleanup of the U12t portal area, skeleton crews were allowed to work in the tunnel because it was considered to be a clean area. Stringent anticontamination procedures were followed for personnel commuting between the check point and U12t tunnel. Hardware recovery was conducted between 1 February and 26 April 1971. On 26 April, the Test Command, Site Development Directorate, Chief Engineer determined that further effort was inadvisable and the drift would be closed on 7 May 1971. From 1 to 7 May, miners retrieved their equipment and several tours were taken through the 01 drift. On 7 May 1971, the 01 drift was officially closed.

6.4.2 Postevent Drilling

No postevent drilling was performed.

6.4.3 Industrial Safety

The portal construction area and the tunnel were hard hat and foot protection areas (safety shoes, safety boots, miner's boots, or toe guards). Each participating agency provided its own safety equipment. All personnel on the initial tunnel reentry teams were certified in the use of the McCaa 2-hour breathing apparatus and had used the Scott-Draeger self-contained breathing apparatus. All standard safety rules and practices as spelled out in the "U.S. Bureau of Mines Manual" were observed.

All explosives, electro-explosive components, solid propellants, toxic material, and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224)
2. AEC Manual 500 Series for the Nevada Test Site
3. Individual Safe Operating Procedures (by experimenter organizations)
4. MINT LEAF Safety Regulations

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DOD Safety Coordinator.

A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive materials, or any other operation with the potential for personal injury. Each individual involved in the project was required to be knowledgeable of the contents of the procedure.

Checks were made during each shift for toxic gases and explosive mixtures. The maximum concentrations of explosive gases were 18,000 ppm hydrogen and 1,800 ppm methane as sampled remotely and analyzed by gas chromatograph. These samples were taken remotely from behind the overburden plug on 7 May 1970, and then recorded in the monitors' log book. Industrial safety codes, including specific codes for mining and drilling, were established by REECo and were emphasized during all operations.

6.5 RESULTS AND CONCLUSIONS

At H+1 minute on 5 May 1970, RAMS unit Nos. 26, 30AT, 31, 32, 33, 34, 35, and 36 showed positive signs of radiation which was due to experiment activation. The maximum reading obtained was 700 R/h at 1320 hours on D-day at unit No. 31 located 820 feet from the zero point. This reading occurred during a release of gases into the tunnel complex. All telemetry was secured at 1115 hours on 2 June 1970.

Initial radiation surveys of the Rainier Mesa trailer park were conducted between 0930 and 1130 hours on D-day. All readings were background. Initial portal radiation surveys were conducted between 0935 and 1015 hours on D-day. All readings again were background. No alpha radiation was detected.

The maximum concentration of toxic gases and explosive mixtures detected was 18,000 ppm hydrogen and 1,800 ppm methane by gas chromatograph sample from behind the overburden plug on 7 May 1970.

During reentries into the 01 drift for experiment recoveries, a maximum gamma exposure rate of 10 R/h was measured 30 feet from the TAPS door on 18 May 1970.

There were no whole body external or internal organ exposures which exceeded the established guides.

Personnel exposures received during individual entries to the MINT LEAF event from 5 May 1970 to 30 April 1971, when the U12t.01 drift was no longer a radex area, are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	2,213	350	24
DOD Participants	390	350	14

CHAPTER 7

HUDSON MOON EVENT

7.1 EVENT SUMMARY

HUDSON MOON was a DOD underground test detonated at 0716 hours PDT on 26 May 1970 with a yield less than 20 kt. The LRL-provided device was emplaced in tunnel U12e.12 at a vertical depth of 1,386 feet (Figure 26). The objective of this test was to evaluate and measure responses of material and equipment to the environment of a nuclear detonation. Government agencies and contractors conducted 26 projects to obtain the desired information. Severe conditions existed in the experiment tunnel soon after detonation. However, essentially all radioactive effluent was contained within the tunnel complex until it was released to the atmosphere using the ventilation system and filters. Minor levels of radioactive effluent were detected onsite, and no radioactive effluent was detected offsite.

7.2 PREEVENT ACTIVITIES

7.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all HUDSON MOON activities in Area 12, subject to controls and procedures established by the Test Manager and the NTSO. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Test Command, DASA, and the AEC Nevada Operations Office.

Project agencies were responsible for designing, preparing,

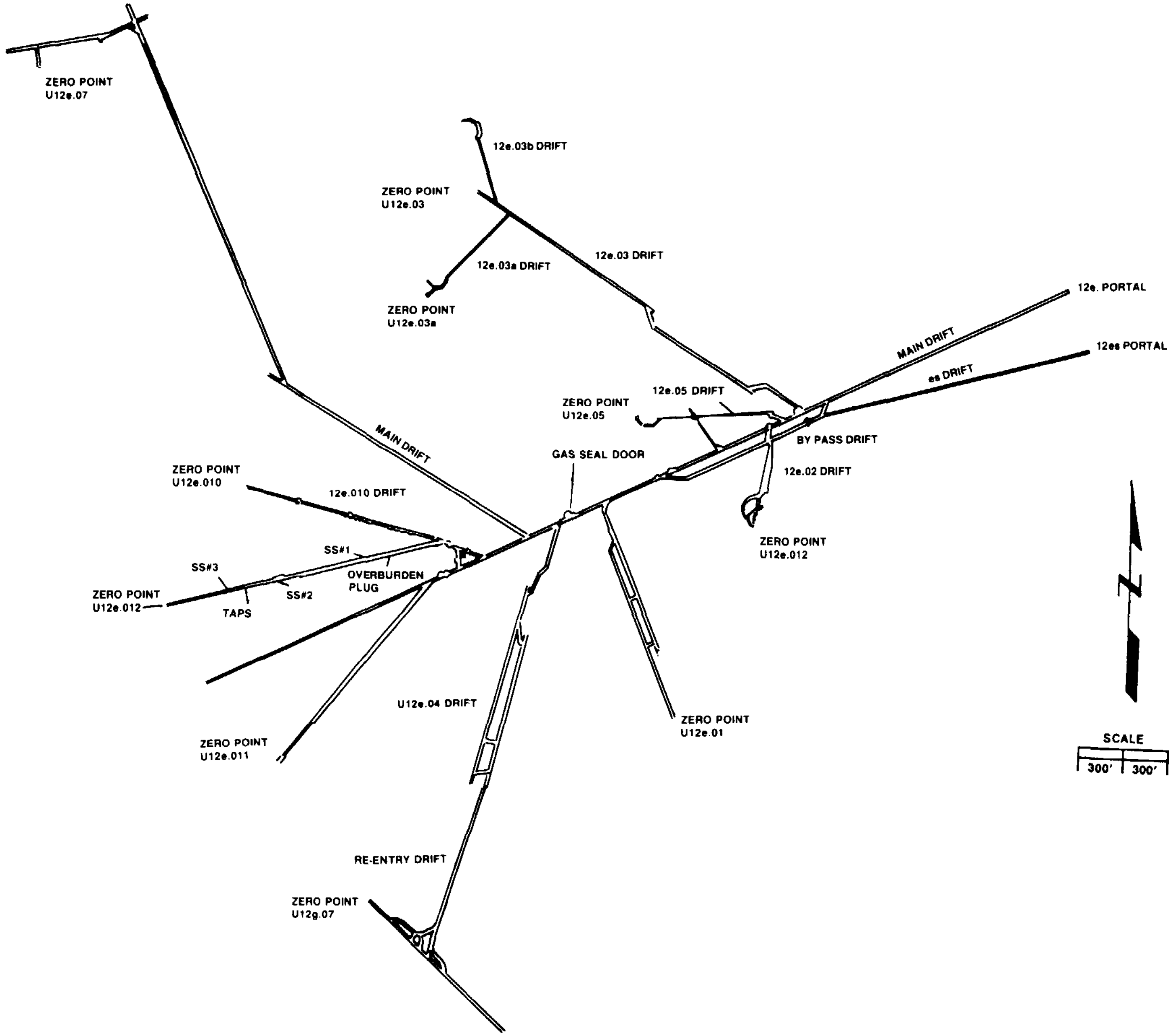

Figure 26. HUDSON MOON Event tunnel layout.

and installing their experiments, or delivering them to an installation contractor for subsequent placement. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

Because LRL fielded the device, the LRL Test Group Director was responsible for radiological safety within a 1,000-foot radius of SGZ, a 1,000-foot radius of the new portal, the trailer park, and the tunnel from the portal to GZ. This responsibility was in effect from device emplacement until device detonation. At that time, the Test Manager relieved the LRL Test Group Director of responsibility and delegated responsibility to the DOD Test Group Director.

7.2.2 Planning and Preparations

A. Tunnel Facilities Construction

Mining of the U12e.12 drift began on 1 April 1969 and was conducted concurrently with construction operations for DIESEL TRAIN in the U12e.11 drift. The turnout of the U12e.12 drift began 306 feet into the U12e.10 (DORSAL FIN) drift. A 10-foot by 10-foot bypass drift was mined around the U12e.10/e.12 intersection where DIESEL TRAIN instrumentation was located. Mining of the drift was completed on 19 September 1969. HUDSON MOON construction activity during October and November 1969 consisted of alcove hardening, instrument hole drilling, and building pads for the LOS pipe components which were installed after DIESEL TRAIN test execution.

Installation of the LOS pipe began on 17 December 1969. The LOS pipe was 1,300 feet long and contained three test chambers. Only one TAPS unit was installed. It was located on the portal side of the sample protection system boxes.

Penetrations through the overburden plug consisted of a 6-foot 6-inch high manway, two 24-inch vent lines, four 1/2-inch reentry gas sampling lines, two 2-inch chiller lines (for vacuum pumps), and a 12-inch drain line.

Facilities constructed for DIESEL TRAIN and other prior events which were reused for HUDSON MOON included the gas seal door, downhole cable alcove, and the portal and Mesa trailer parks. The pipe and tunnel configuration for HUDSON MOON were designed to provide containment of the weapons debris and energy within the first few hundred feet of the LOS pipe. The stemming design was based on successful designs employed on several previous events and was scaled to the HUDSON MOON anticipated yield.

Event readiness was set for June 1970. In late September 1969, based upon anticipated labor difficulties at the NTS, the event date was advanced to 19 May 1970. Zero room installation was completed in mid-December after the DIESEL TRAIN event was executed. By 30 January 1970, the LOS pipe was installed, and the first vacuum check was successfully completed on 13 February. The entire LOS pipe was installed, pressure checked, and vacuum checked by 23 March. From 22 March to 29 April, experimenters installed their experiments in the three test chambers.

Advance warning indicated that the skilled labor workers were planning to go on strike at some date after the first of June 1970, requiring that a large number of events be executed before that date. This fact had compressed six major events into the month of May. Consequent demands on facilities, instrumentation, and personnel to handle the workload made the readiness dates of later events dependent upon the execution dates of the earlier ones. The planned mandatory full participation dry run date and event date for HUDSON MOON were set back one week when MINT LEAF was delayed by bad weather for seven days.

The mandatory full participation (MFP) dry run was attempted three times on 12 May. Problems appeared in several experiments, mostly as a result of the demands made on experimenters from other test events. There were three more attempts made on 13 May and late in the evening the MFP was considered successful. The following day, a successful full-power, full-frequency (FPFF) dry run was completed.

B. Radiological Safety Support

Procedures for radiation exposure and contamination control during this event were in accordance with requirements of responsible DOD and SLA representatives. Radsafe provided monitoring and equipment support, air sampling, and telemetry.

Detailed radiological safety reentry plans ("HUDSON MOON Reentry Plan") were prepared and issued for implementation to participating agencies prior to the test. Reference markers and air sampling equipment were positioned in the test area. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial surface radiation surveys and aerial surveys by helicopter, and participate in reentry parties, as needed. Radsafe personnel also were standing by at the FCP prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support

RAMS units for the HUDSON MOON event were located as shown in Table 8, Figure 27 and Figure 28.

Two air sampling units (M-102s) were positioned, one at the U12e portal and one at the U12es portal.

PHS personnel had positioned 99 air sampling units and 30 gamma rate recorder stations in the offsite area, and fielded 28 personnel for surveillance activities.

The Pagoda sampling trailer was used to sample the vent lines. Four heads were used with two samplers before the filter boxes and two after the filter boxes. All the cartridges used were the standard activated charcoal type.

D. Security Coverage

Device security procedures in the zero point area and

Table 8. HUDSON MOON Event RAMS unit locations.

Station	Location
	SURFACE
1	Directly above e portal
2	Directly above es portal
3	300 feet at 337° azimuth from e portal
4	250 feet at 25° azimuth from e portal
5	300 feet at 90° azimuth from e portal
6	225 feet at 340° azimuth from es portal
7	300 feet at 250° azimuth from e portal
8	245 feet at 303° azimuth from e portal
9	125 feet at 45° azimuth from es portal
10	300 feet at 102° azimuth from es portal
11	300 feet at 180° azimuth from es portal
12	300 feet at 237° azimuth from es portal
13	300 feet at 286° azimuth from es portal
14	On the filter system and the blower stacks
15	On the filter system and the blower stacks
16	On the filter system and the blower stacks
17	2,250 feet at 60° azimuth from RAMS station No. 6
18	2,500 feet at 102.5° azimuth from RAMS station No. 6
19	1,100 feet at 128° azimuth from RAMS station No. 6
20	1,655 feet at 254° azimuth from RAMS station No. 6
21	2,500 feet at 329° azimuth from RAMS station No. 6
22	200 feet at 180° azimuth from cable hole No. 2
23	220 feet at 90° azimuth from cable hole No. 2

Table 8. (Concluded)

Station	Location
	SURFACE (Concluded)
24	At cable hole No. 2
25	225 feet at 270° azimuth from cable hole No. 2
26	250 feet at 0° azimuth from cable hole No. 2
27	700 feet at 30° azimuth from SGZ
28	670 feet at 135° azimuth from SGZ
29	700 feet at 300° azimuth from SGZ
	UNDERGROUND
30	1,075 feet into U12e.12 experiment drift
31	525 feet into U12e.12 experiment drift
31AT*	400 feet into U12e.12 experiment drift
32	260 feet into U12e.12 experiment drift
34	250 feet into U12e.10 drift
35	605 feet into U12e.06 drift
36	150 feet into U12e.06 drift
36AT*	150 feet into U12e.06 drift
37	3,475 feet into U12e main drift
38	3,425 feet into U12e main drift
39	2,885 feet into U12e bypass drift
40	1,850 feet into U12e bypass drift
41	50 feet into main drift from e portal
42	95 feet into main drift from es portal

*Buried

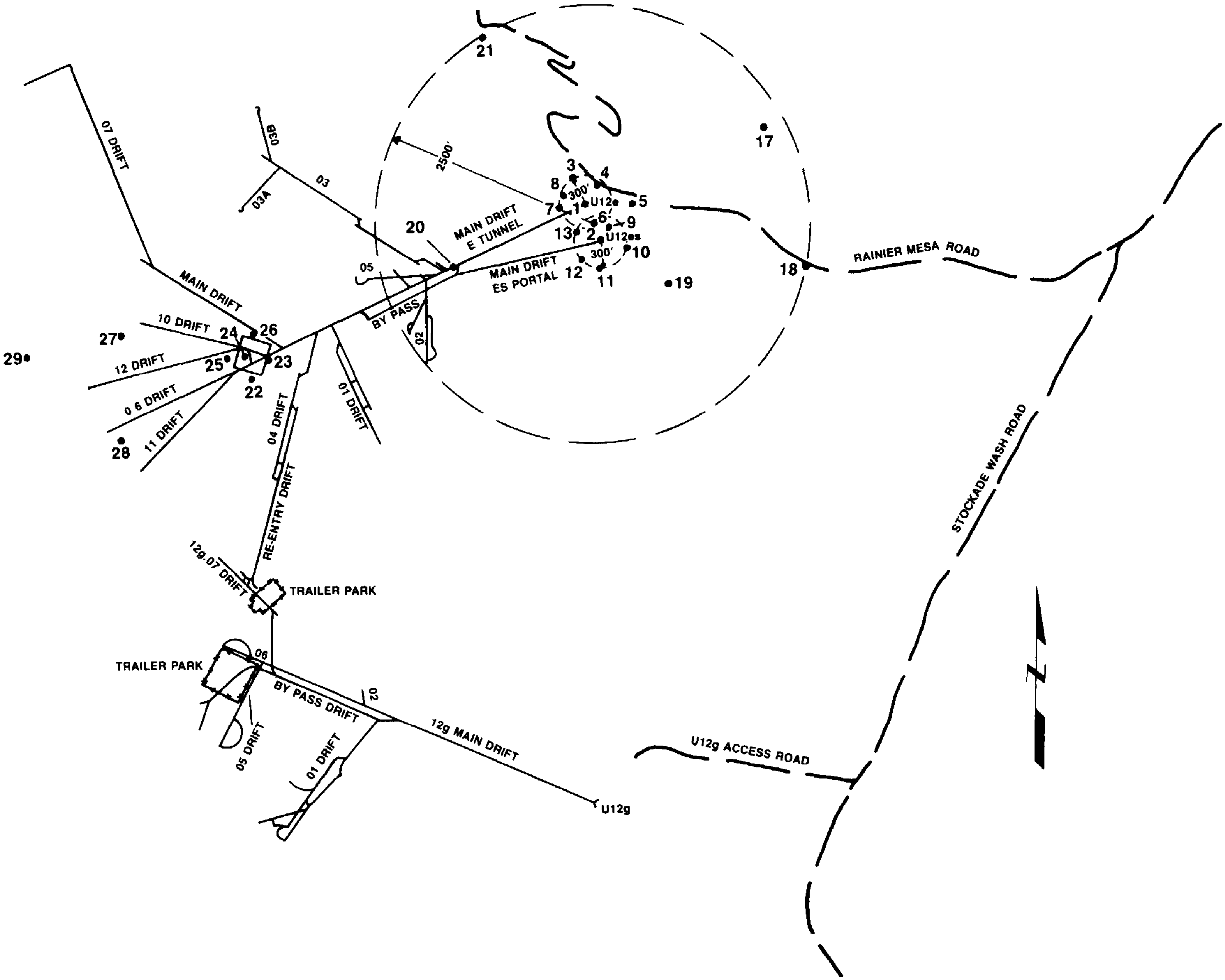

Figure 27. HUDSON MOON Event surface RAMS unit locations.

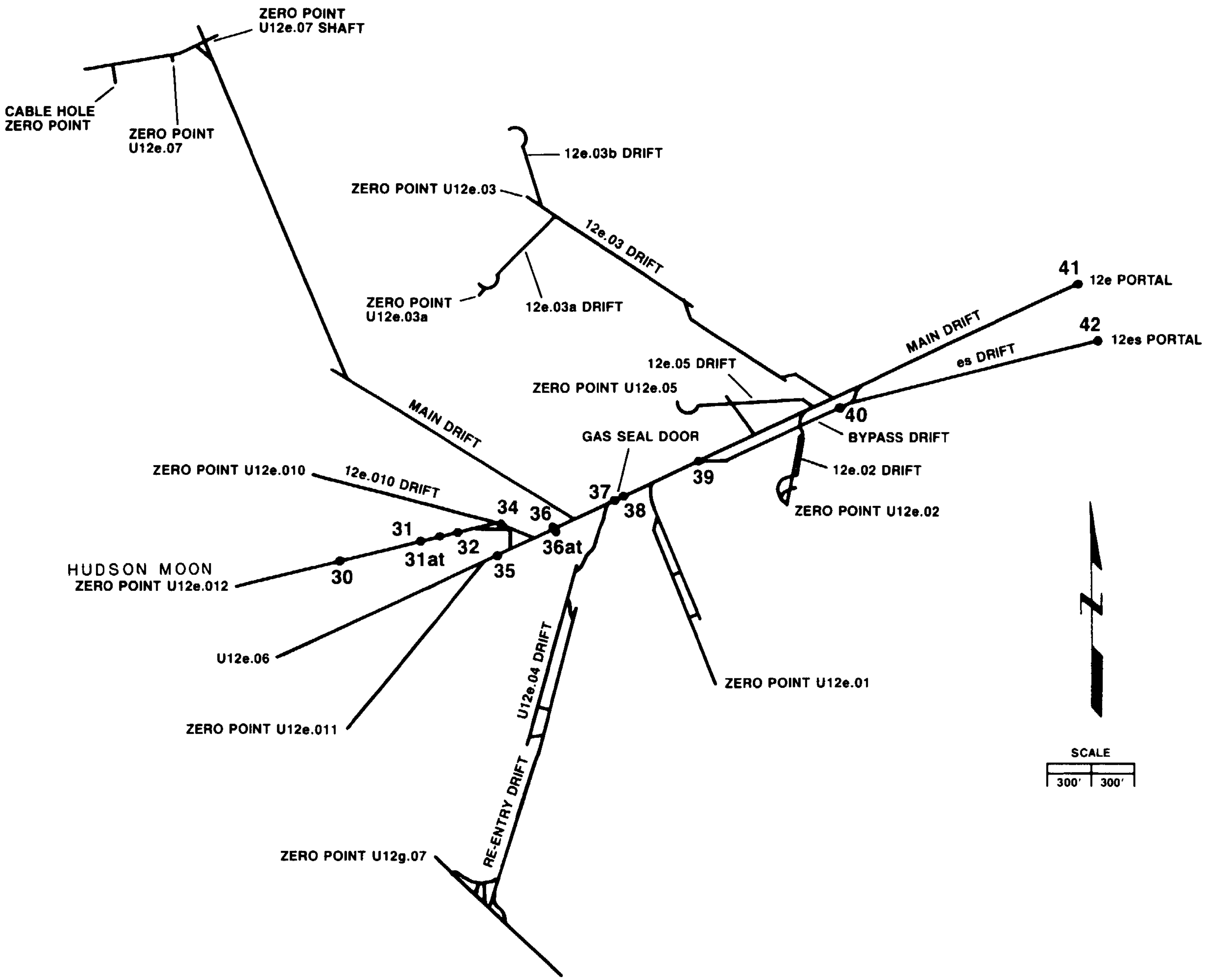

Figure 28. HUDSON MOON Event underground RAMS unit locations.

the timing and firing control room were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

All personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges, or issue and return of muster badges. After area control was established, all through traffic was diverted by use of screening stations.

E. Air Support

A USAF UH-1F helicopter with crew performed aerial photography. Two UH-1N helicopters and crews were provided by the Air Force; one was used to perform security sweeps, and the other was for cloud tracking and Test Manager's standby use. The USPHS provided PHS monitoring personnel for one USAF U-3B aircraft with military crew to perform cloud tracking; a Turbo Beech aircraft for cloud sampling; and a Turbo Beech aircraft on standby at McCarran Airport in Las Vegas to perform cloud sampling, if needed. A Martin 404 also was on standby at McCarran Airport in Las Vegas for cloud tracking, if needed. Geotronics personnel in a Cessna 180 provided postevent photography coverage.

7.2.3 Late Pre-event Activities

The tunnel button up for the final dry run was completed at approximately 0830 hours on 25 May 1970. The final dry run was started at 1300 hours but was held for false monitor indications several times. By 1500 hours, the final dry run was successfully completed. The 1430-hour readiness briefing indicated favorable weather conditions for test execution on 26 May 1970.

Button up activities were performed by personnel representing DOD, LMSC, SLA, LRL, SRI, EG&G, LASL, ETI, AFWL, PI, NOL, MRC, GA, and KN. The manway door in the overburden plug was closed and sealed after completion of button up activities by the experimenters.

Security sweeps of the closed area were performed.

7.3 EVENT-DAY ACTIVITIES

At 0318 hours on D-day, permission to arm the device was granted. The first manually sent signal was activated at 0600 hours. At 0645 hours, the fifteen minute countdown began. All systems functioned until minus five minutes, at which time an LRL experiment failed to come on. The countdown was held for eight minutes while the problem was analyzed, then backed up to minus 10 minutes and restarted.

HUDSON MOON was detonated at 0716 hours PDT on 26 May 1970.

7.3.1 Test Area Monitoring

Shortly after test execution, readings greater than 1,000 R/h were measured on the zero point side of the overburden plug. RAMS units outside the overburden plug indicated gas leakage through the plug at about 0719 hours. At 0725 hours, readings greater than 1000 R/h were detected by RAMS unit No. 32 on the portal side of the overburden plug, and radioactive effluent had begun to leak through the gas seal door. By 0746 hours, RAMS units (Nos. 30, 31, and 31AT) on the zero point side of the overburden plug ceased functioning. Some units located between the overburden plug and the gas seal door detected levels greater than 1,000 R/h at this time. Readings in this area of the tunnel complex began steadily decreasing after 1006 hours.

At 0924 hours, RAMS units on the filter system indicated a buildup of activity on the filters. At 0936 hours, the radioactive gas had percolated through the filter system and was being released to the atmosphere. Although the ventilation system was not being operated at the time, activity was drawn out of the tunnel through the vent line. This was apparently due to natural ventilation, which had been observed preevent while the filters were being installed in the system. The natural ventilation continued through the night and the estimated total release for the first 24 hours was 2,270 curies. Twelve hours after the filtered effluent was released, this activity would have decayed to 790 curies.

At 0835 hours on D+1, with the permission of the Test Manager, the ventilation system was turned on and the tunnel was ventilated from the portal to the gas seal door to insure that the activity which leaked through the gas seal door was filtered before release to the atmosphere. The system was operated for 68 minutes during which time an estimated 500 curies of gaseous activity were released. At release plus 12 hours, radioactive decay would have reduced this activity to 325 curies.

Telemetry measurements were discontinued at 1126 hours on 18 July 1970.

7.3.2 Initial Rainier Mesa Trailer Park and Portal Trailer Park Radiation Surveys and Data Recovery Activities

Initial Radsafe survey teams, along with data recovery teams, entered the Mesa trailer park at 0912 hours. A survey of the trailer park resulted in a maximum reading of 1 mR/h at the cable hole.

Between 1150 and 1308 hours a gas chromatograph team sampled the tunnel atmosphere from the HP-2 trailer located at the portal. The maximum exposure rate during this time was 200 mR/h at 1245 hours at the pump outside the HP-2 trailer. An LRL data recovery team, accompanied by a Radsafe monitor, performed recovery operations at the portal trailer park between 1325 and 1447 hours.

Surface data recoveries were completed and all personnel exited the area by 1500 hours.

7.4 POSTEVENT ACTIVITIES

7.4.1 Tunnel Reentry and Experiment Recovery Activities

On 27 May at 0835 hours, the ventilation system was turned on and the tunnel was ventilated from the portal to the gas seal door. Maximum readings were 1,000 ppm methane; 2,100 ppm hydrogen; 5,000 ppm carbon dioxide; and 4,000 ppm carbon monoxide. This ventilation effort, which had been approved by the Test Manager, continued for approximately one hour with all effluent being passed through a filter system before release to the atmosphere. The labor strike which began on 31 May 1970 caused recovery operations to be stopped after the initial surveys. The tunnel complex was then closed, except for remote gas sampling, for more than a month to allow radiation levels to decrease.

On 7 July at 0900 hours, the volume between the gas seal door and the overburden plug was ventilated for four to five hours before the overburden plug valves were opened. A PHS sampling aircraft made several passes over the portal area and the areas downwind from the portal while ventilation was in progress. All readings were background. On 8 July, a PHS aircraft circled the portal area and collected one mass air sample, one cryogenic sample, and three grab samples. All samples indicated background radiation levels. Ventilation of the entire tunnel continued for approximately one week. During this time, approval was received for reentry to begin on 14 July.

On 14 July, initial tunnel reentry began at 0938 hours. Team No. 1, dressed in anticontamination clothing and Scott-Draeger self-contained breathing apparatus, checked the tunnel to the gas seal door. The gas seal door, which was inspected and found to have no leaks, was subsequently opened. No toxic gases or explosive mixtures were detected and a 3 mR/h exposure rate was measured. An air pump for tunnel dewatering was established with a discharge to a drain line in the trench inside the gas seal door. Team No. 1 then returned to the portal. Team No. 2 entered the tunnel at 1205 hours and established railroad tracks through the gas seal door. The team then walked-out the tunnel to the U12e.12 bypass drift. The maximum radiation reading obtained was 6 mR/h at the junction of the bypass drift and the U12e.12 'Y'. Team No. 2 exited the tunnel at 1330 hours.

Two teams reentered the tunnel on 15 July. The first team entered at 0925 hours, established a compressed air line at the gas seal door, and proceeded to walk-out U12e.06 and U12e.10; check out the cable alcove plug; and walk-out U12e.12 to the overburden plug. Gas samples were taken through the overburden plug and the team began removing bolts from the door. After completing this task, the team exited the tunnel at approximately 1330 hours. The maximum exposure rate of 400 mR/h was detected inside the manway of the OBP.

Efforts between 16 and 21 July were concentrated on removing sandbags from the overburden plug manway door. The exposure rate in this work area was 40 mR/h; no toxic gases or explosive mixtures were detected. After the sandbags were removed, crews were sent in to clean up the area on the portal side of the overburden plug. Teams were using full-face masks with Acme canisters, based on results from samples previously taken. It also was necessary to repair the vent line on the portal side of the overburden plug. Teams worked in two-hour shifts in an effort to keep exposure levels low. An additional team surveyed the tunnel and obtained air samples to see if a fresh air station could be established underground.

The staging area (fresh air station) for test chamber No. 1 reentry teams was on the portal side of the overburden plug. A rescue team also was staged at this location. The rescue team had McCaa self-conained breathing apparatus available, if needed. Team No. 1 departed the overburden plug at 1018 hours on 22 July with radiation readings increasing from 1.5 R/h just past the thermal shield to 3.5 R/h as they reached the test chamber door. After opening the test chamber door, radiation levels remained the same, and no toxic gases or explosive mixtures were detected. The team returned to the fresh air station at 1045 hours. Subsequently, a scientific assessment team entered the test chamber to evaluate the condition of the experiments and take photos. After review by the scientific assessment team, it was decided, for safety reasons, that recovery would be accomplished through a parallel drift to be mined 50 feet from the left rib of the experiment drift; Figure 29 shows the parallel drift at completion of recovery operations.

On 5 August 1970, REECo began mining a 10-foot by 10-foot reentry drift in the left rib of the U12e.12 project drift. The reentry drift was stopped on 25 August and a 10-foot by 10-foot crosscut (crosscut No. 1) was started toward test chamber No. 1. The floor of crosscut No. 1 was graveled and sandbagged, and ribs were sandbagged to provide a shielded walkway to the LOS pipe. Two gas sampling holes were drilled into the test chamber. No toxic gases or explosive mixtures were detected.

After being made aware of a potential toxic gas problem, the necessary materials were prepared and specific checks were made

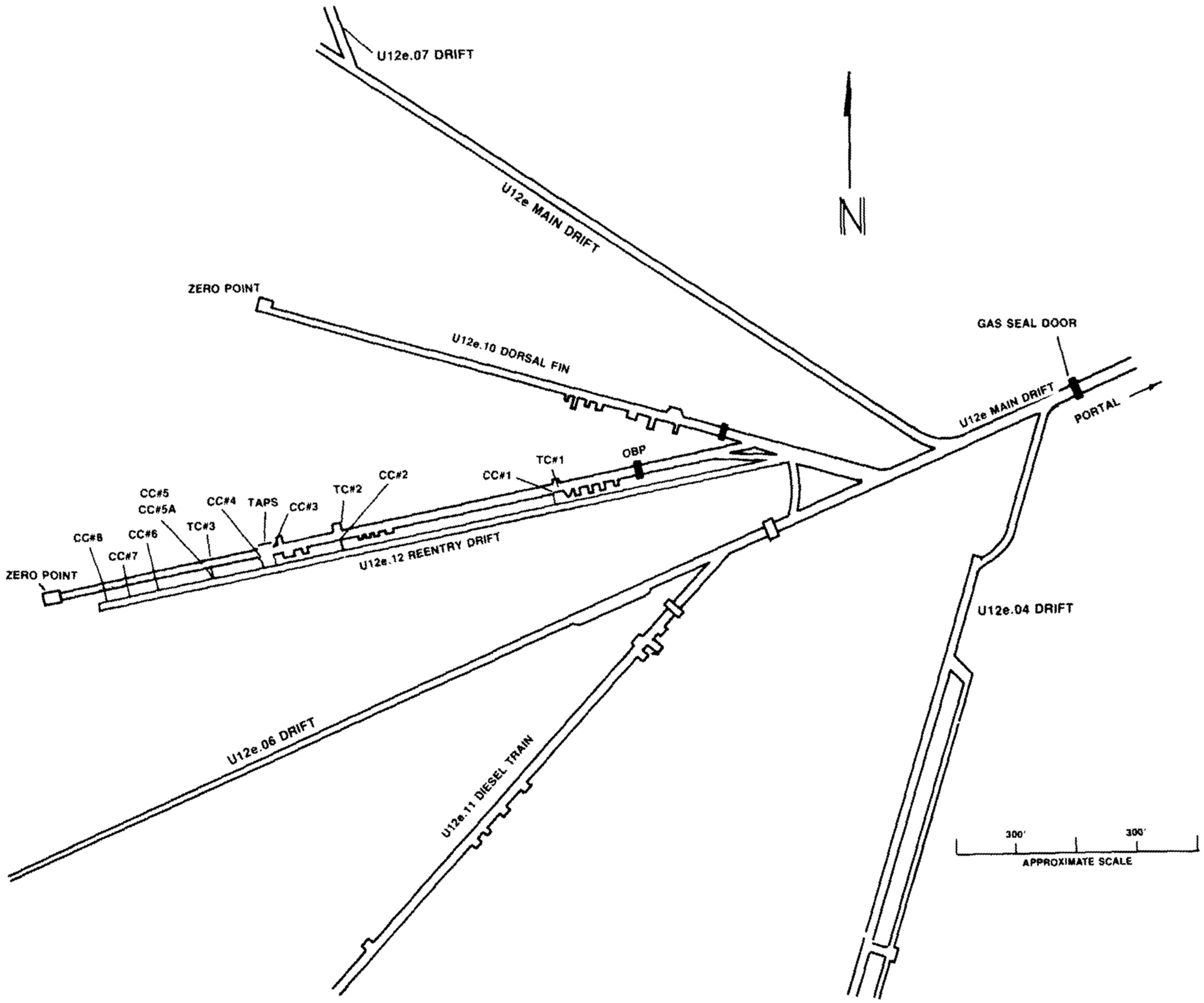

Figure 29. HUDSON MOON Event postevent reentry tunnel layout.

for hydrogen cyanide, which was a potential breakdown product from materials used in the experiment, by drilling holes through the pipe at two locations. None was detected. An unsuccessful attempt also was made to siphon a water sample from one of the drilled holes. After these tests were conducted, a three-foot by six-foot doorway was cut in the wall of test chamber No. 1. The torch operator wore an MSA all-purpose mask with canister while performing this operation, in addition to the required anti-contamination clothing. A reentry team entered the test chamber on 28 August. Their instruments detected no carbon monoxide, toxic gases, or explosive mixtures. They did detect 500 to 1,000 ppm carbon dioxide. Ventilation appeared to be adequate in the pipe. Gamma radiation readings were 700 to 1,000 mR/h in the test chamber. About six to eight inches of water was on the test chamber floor, along with some experimental debris. Part of this water was pumped out through the original test chamber door to the floor of the LOS drift.

On 31 August, closer examination of experiments by scientific personnel led to a decision to radiograph primary experiments in place to see if there was internal damage. This delayed experiment recovery for several days. Lagging was placed in the bottom of test chamber No. 1 to improve the footing and prepare it for radiography. By 2 September, radiography had been conducted and the results analyzed by LRL personnel, who made the decision to go ahead and remove the experiments from the test chamber. The day was spent in preparing a runway to move the experiments out of the pipe. On 3 September, all primary experiments had been moved to the U12e.06 drift for additional radiography. No problems were encountered while moving the experiments. Personnel most heavily involved in this effort received approximately 800 to 900 mrem exposure as estimated by pocket dosimeters. Radiography continued through 9 September, at which time all other experimenters were allowed to begin removing their experiments from the test chamber. The exposure rate in the test chamber during experiment recovery activities was generally 300 to 400 mR/h. All major experiments were recovered from this test chamber by the end of the day on 11 September.

From 12 September to 1 October, mining toward test chamber No. 2 was conducted. Crosscut No. 2 toward test chamber No. 2 was completed by 5 October. The gamma radiation measurement two feet from the test chamber and four to five feet above the floor was 2 R/h. Radiation levels inside the test chamber were estimated to be 4-5 R/h. The floor and ribs of crosscut No. 2 were shielded with sandbags as was done at test chamber No. 1. This reduced radiation levels to 300-500 mR/h. A test hole was drilled into test chamber No. 2 for sampling purposes. No toxic gases or explosive mixtures were detected.

On 6 October, a 2 by 3-foot hole (port) was cut into test chamber No. 2, and the chamber entered by a team dressed in double anticontamination suits, hoods, booties, and gloves, and wearing a full-face mask. Initial observations revealed no gross disorientation of any experiments. The entire test chamber was covered with deep (12-inch) layers of fine dust or ash, gray in color. There were no indications of debris damage, although the dust would have masked it. Just above the test chamber door (opposite the recovery access port) a view port with its transparent material missing created an opening from the test chamber to the drift, and some rocks were lodged in the short stub leading to the port. Radiation levels during reentry ranged from 6 R/h at the access port to 25 R/h at contact with the ash on the floor.

The first attempt at removing the dust from the test chamber involved a slurry technique. Water was added to the dust and the resulting mixture was pumped out of the test chamber and into the experimental drift. This technique was employed carefully so that water was not sprayed on any of the experiments. As areas in the test chamber were cleared, sandbags and lagging were placed where possible to further reduce radiation levels. A brief attempt to vacuum the experiments was made as decided by the test group staff, but was discontinued when it was decided that this should be left to the experimenters. The radiation measurement in the test chamber was originally 3 R/h; however, after cleanup efforts, this was reduced to 450 mR/h. To further reduce individual exposures, mining personnel assignments also were rotated. All personnel were dressed in full anticontamination clothing and respiratory protection equipment for work in the test chamber area.

By 12 October, the access port had been enlarged, the area had been sandbagged, and a plywood walkway prepared into the test chamber. This allowed experiment recovery operations to begin on 13 October. Exposure rates to recovery personnel varied from 300 to 750 mR/h, depending on the work location. Experiment recovery operations were performed by personnel representing LRL, SLA, LMSC, and DOD. These operations continued through 16 October.

Between 5 and 10 November 1970, attempts were made to reenter the LRL alcove to recover experiments. Personnel dressed-out in anticontamination clothing and respiratory protection equipment and attempted to enter the alcove; however, recovery operations were cancelled due to exposure rates of 1 to 2 R/h in the main drift. The crosscut was sealed, and all personnel exited the drift.

In an effort to gather data on containment problems incurred during this event, reentry mining was continued, although no further experiment recoveries were performed. Crosscut No. 3 was driven to intersect the LOS pipe approximately 20 feet on the portal side of the TAPS door, and an opening was cut into the pipe on 9 December 1970. Crosscut No. 4 was driven on the zero point side of the TAPS and was completed on 15 February 1971.

From 16 February until 12 March 1971, the LOS pipe was cut and the stemming material was removed. Crosscut No 5 was driven to intersect test chamber No. 3, but on holing through, the pipe drift was found to be two-thirds full of rock rubble and radiation levels reaching 30 R/h discouraged further excavation at this location. Crosscut No. 5A was driven from crosscut No. 5 to intersect the pipe within the high-strength grout on the zero point side of test chamber No. 3. High radiation levels at crosscut No. 5A prevented extensive investigation. Crosscut No. 6 was driven through to the LOS pipe drift and completed during the week of 26 July 1971. Crosscut No. 7 was driven to intersect the LOS pipe drift and crosscut No. 8 was driven to the left rib of the pipe drift.

7.4.2 Industrial Safety

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive materials, or any other operation with the potential for personal injury. Each individual involved in the project was required to be knowledgeable of the contents of this procedure.

All explosives, electro-explosive components, solid propellants, toxic material, and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224)
2. AEC Manual 500 Series for the Nevada Test Site
3. Individual Safe Operating Procedures (by experimenter organization)
4. HUDSON MOON Safety Regulations

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DOD Safety Coordinator.

The portal construction area and the tunnel were hard hat and foot protection areas (safety shoes, safety boots, miner's boots, or toe guards). Each participating agency provided its own safety equipment. All personnel on the initial tunnel reentry teams were certified in the use of McCaa 2-hour breathing apparatus and had used the Scott-Draeger self-contained breathing apparatus. All standard safety rules and practices as spelled out in the "U.S. Bureau of Mines Manual" were observed.

Checks were made on each shift for toxic gases and explosive mixtures. These measurements were recorded in the Radsafe monitors' log book. Industrial safety codes including specific codes for mining, tunneling, and drilling were established by REECo and emphasized during all operations.

Maximum concentrations of gases detected were 1,000 ppm methane, 2,100 ppm hydrogen, 5,000 ppm carbon dioxide, and 4,000 ppm carbon monoxide. These readings were remotely detected from the zero point side of the overburden plug on 27 May 1970.

7.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 0717 hours on 26 May 1970. Immediately, RAMS unit Nos. 30 and 31 were off scale at greater than 1,000 R/h. RAMS unit No. 31AT went off line at 0720 hours. All telemetry was secured at 1126 hours on 18 July 1970.

The initial surface survey and recovery teams entered the area and took measurements from 0912 to 1500 hours on 26 May 1970. The labor strike which began on 31 May 1970 caused recovery operations to be stopped after the initial surveys.

Initial reentry and recovery operations into the tunnel began at 0938 hours on 14 July and were completed on 10 November 1970. The maximum radiation reading was 25 R/h in test chamber No. 2 on 6 October. Maximum concentrations of gas detected were 1,000 ppm methane; 2,100 ppm hydrogen; 5,000 ppm carbon dioxide; and 4,000 ppm carbon monoxide.

There were no whole body external or internal organ exposures which exceeded the established guides.

Personnel exposures received during individual entries to the HUDSON MOON event from 26 May to 18 December 1970 when use of Area Access Registers was discontinued, are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	4,559	715	27
DOD Participants	427	545	89

CHAPTER 8

DIAGONAL LINE EVENT

8.1 EVENT SUMMARY

The DIAGONAL LINE device was detonated with a yield less than 20 kt at 1215 hours PST on 24 November 1971. LLL provided the device, which was emplaced in a 66-inch diameter cased hole at a depth of 867 feet at shaft site U11g (Figures 30 and 31). Also, a satellite hole was drilled 22 feet west of U11g to obtain geology, ground motion, and containment-related data. The objective of this weapons effects test was to evaluate the response of materials and equipment to a nuclear detonation environment. Government agencies and contractors conducted 19 projects to obtain the desired weapons effects information.

A subsidence crater formed 14 minutes and 30 seconds after zero time. Data recovery was completed at H+2.5. About three hours and 15 minutes after detonation, seepage of radioactive gases was detected in the vicinity of the crater. Release of radioactive gases continued sporadically throughout the night. All readings in the vicinity of SGZ returned to background by early morning. Radioactive effluent slightly above background was detected offsite on 25 November by aircraft only.

8.2 PREEVENT ACTIVITIES

8.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all DIAGONAL LINE activities in Area 11. Responsibilities of AEC and AEC-contractor personnel were in accordance with estab-

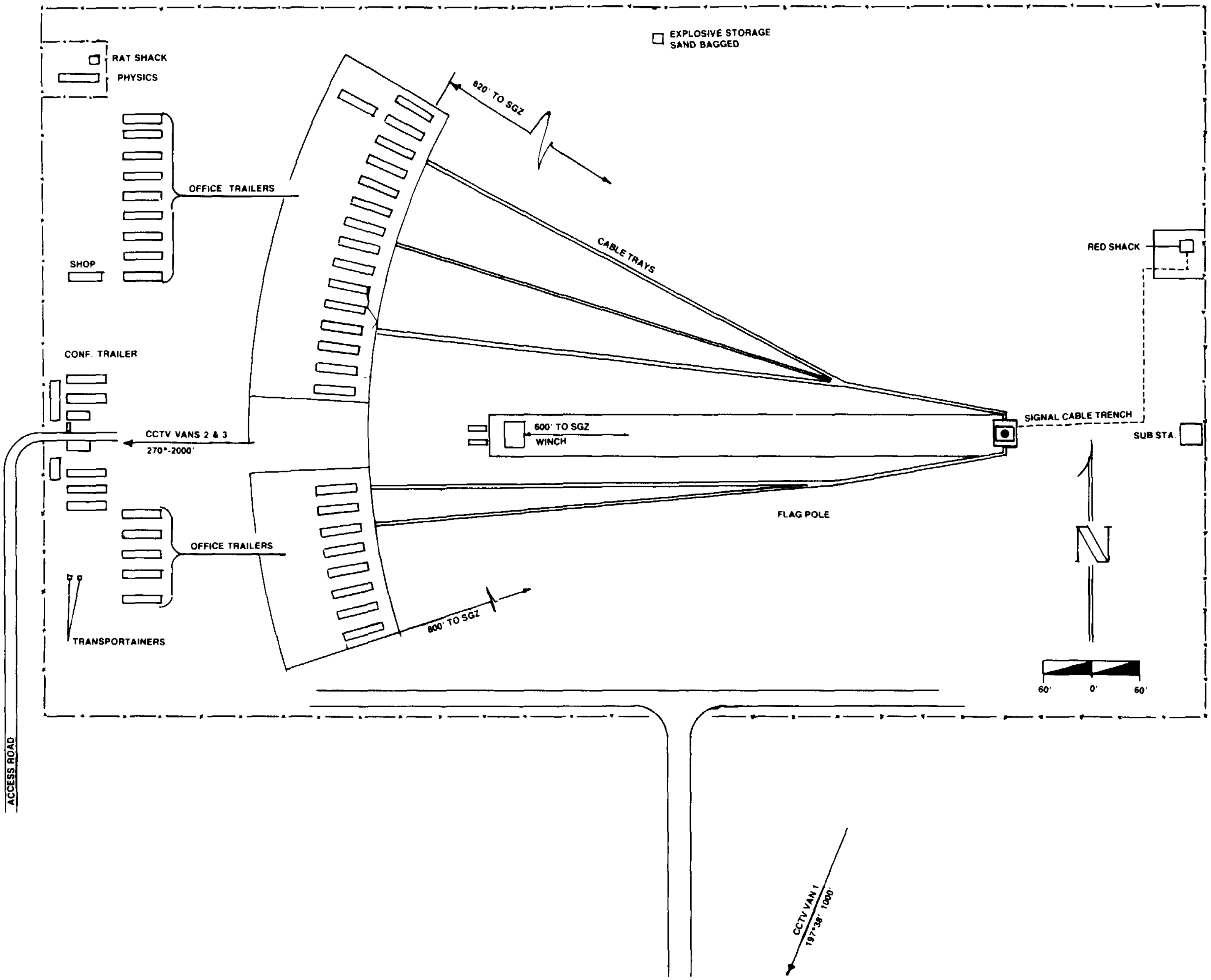

Figure 30. DIAGONAL LINE Event trailer park layout.

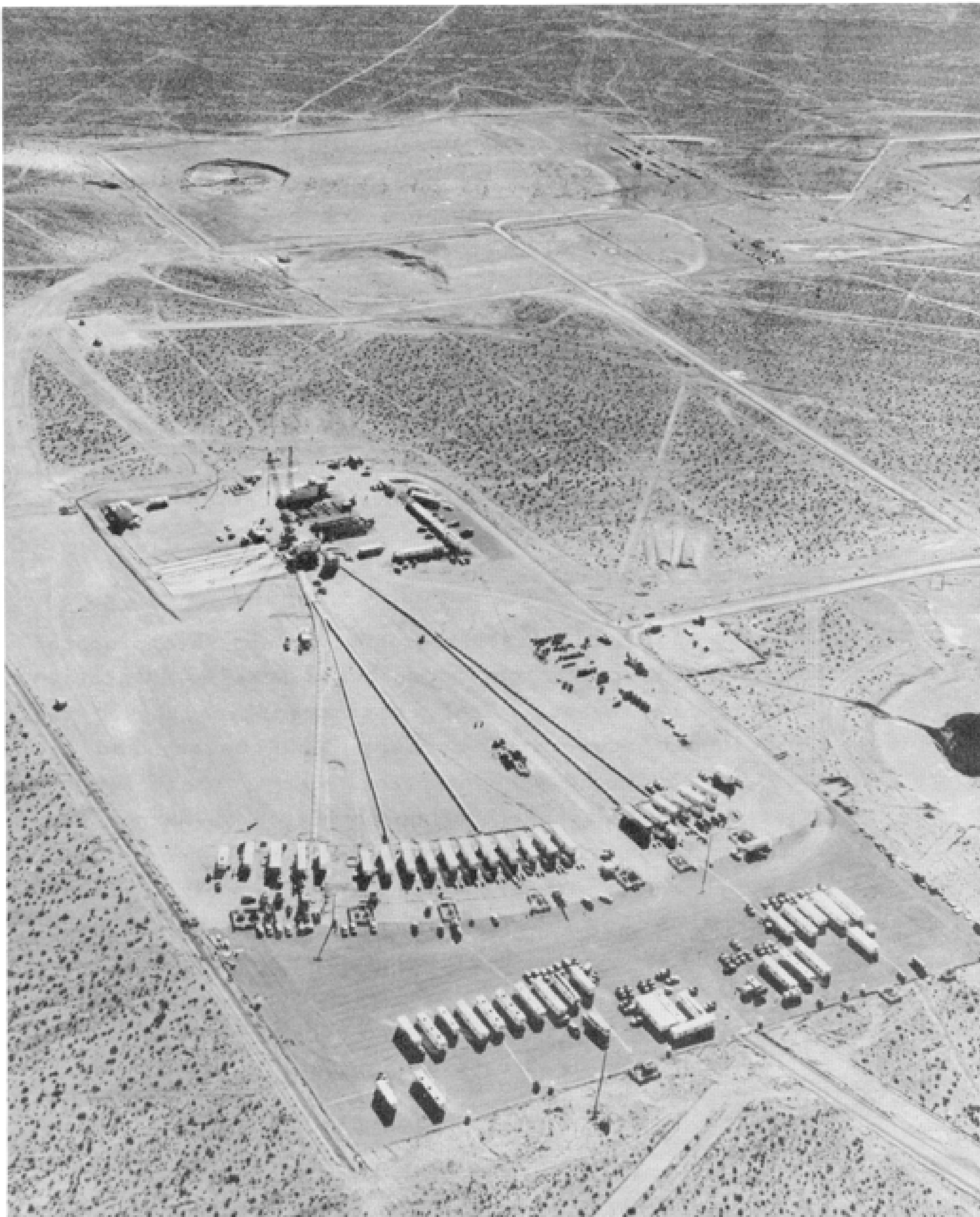

Figure 31. DIAGONAL LINE Event trailer park photo.

lished AEC/DOD agreements or were the subject of separate action between Field Command, DNA, and the AEC Nevada Operations Office. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities. The LLL Test Group Director was responsible for radiological safety within a 3,000-foot radius of SGZ.

8.2.2 Planning and Preparations

A "DIAGONAL LINE Reentry Plan" described preevent preparations and postevent procedures used to assure safe and economical reentry. Radsafe personnel were provided with "Detailed Initial Reentry Procedures" for reentry and recovery operations.

A. Radiological Safety Support

Detailed radiological safety reentry plans were prepared and issued to participating agencies for implementation prior to the event. Test area maps which showed the locations of reference markers, RAMS units, and air sampling equipment were prepared. Party monitors were briefed regarding their responsibilities at manned stations and security stations, and during reentry and sample recovery operations. All personnel at manned stations were provided with anticontamination clothing and respiratory protection equipment, and Radsafe monitors were in attendance. Available clothing and equipment included coveralls, head and shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags and masking tape.

A mobile issue facility stocked with anticontamination clothing, respiratory protection equipment, and dosimetric devices was positioned, prior to the event, at the security barricades near the FCP. A personnel and vehicle decontamination facility was established adjacent to the mobile issue facility.

B. Telemetry and Air Sampling Support

Eighteen RAMS units were installed for this event (Table 9 and Figure 32). All telemetry stations were to remain active until the Test Controller authorized deactivation.

Four air sampling units (M-102) were placed at the following locations:

1 - 600 feet due north of SGZ
1 - 600 feet at 45° azimuth from SGZ
1 - 600 feet at 60° azimuth from SGZ
1 - 600 feet at 330° azimuth from SGZ

The Environmental Protection Agency fielded 29 personnel to perform surveillance activities.

C. Security Coverage

Device security procedures in the zero point area and the timing and firing control room were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

Muster and control stations were established. All personnel were required to have proper security clearances for the area. Control of the area was maintained by using roadblocks, access authorizations, and the "Test Manager's Operations Plan -- DIAGONAL LINE." WSI security guards were responsible for activating roadblocks and directing traffic flow.

Table 9. DIAGONAL LINE Event RAMS unit locations.

Station	Location (from SGZ)
1	On SGZ experimental tower
2	At SGZ
3	300 feet at 0° azimuth
4	600 feet at 0° azimuth
5	600 feet at 45° azimuth
6	600 feet at 90° azimuth
7	600 feet at 135° azimuth
8	600 feet at 180° azimuth
9	600 feet at 225° azimuth
10	800 feet at 255° azimuth
11	800 feet at 265° azimuth
12	800 feet at 285° azimuth
13	800 feet at 300° azimuth
14	600 feet at 330° azimuth
15	2,000 feet at 0° azimuth
16	2,000 feet at 90° azimuth
17	2,000 feet at 180° azimuth
18	2,000 feet at 270° azimuth

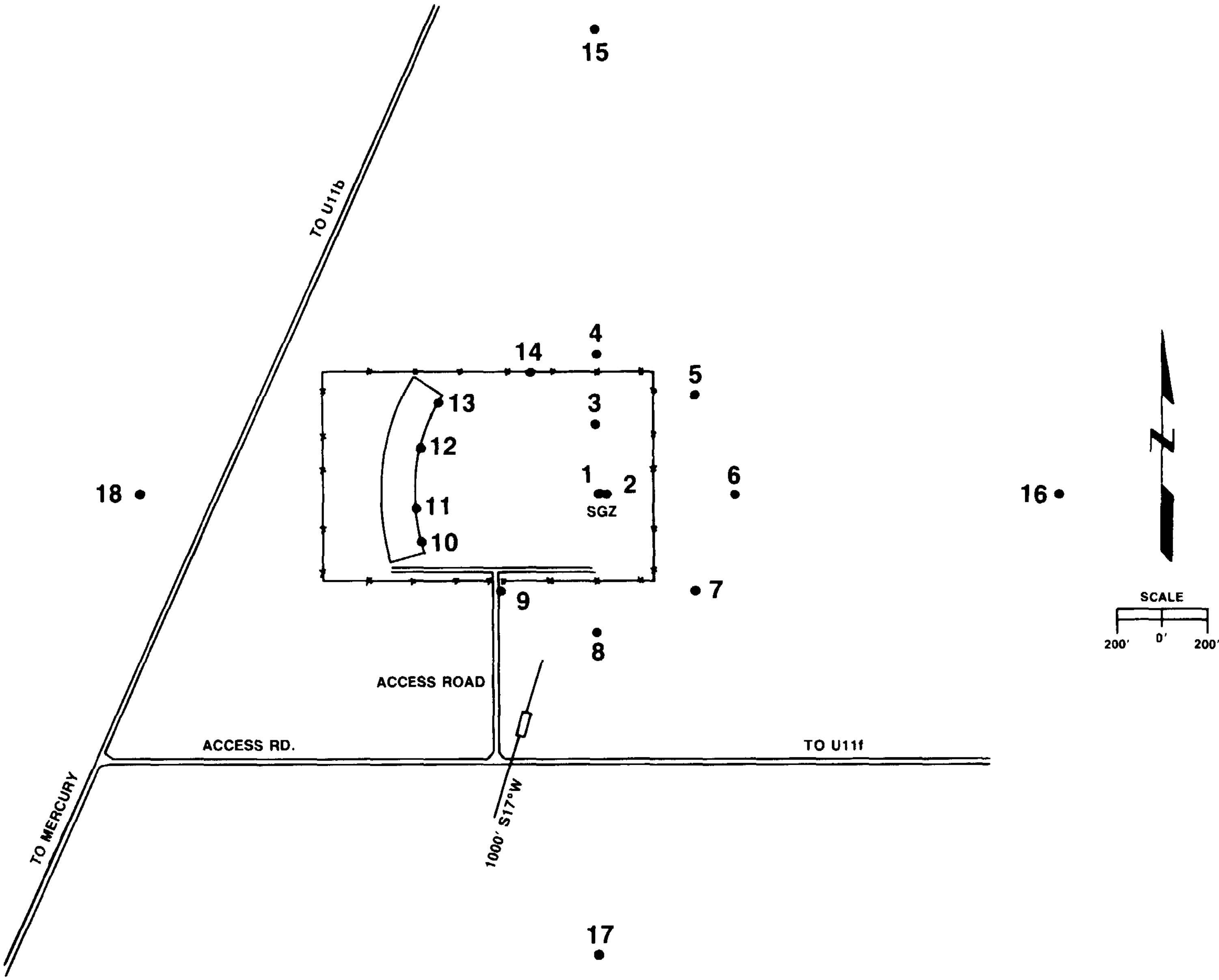

Figure 32. DIAGONAL LINE Event RAMS unit locations.

D. Air Support

One UH-1N helicopter and one UH-1F helicopter with crews were provided by the U.S. Air Force to perform security sweeps and provide closed circuit television coverage. The USAF also provided a U-3B aircraft and crew to support Environmental Protection Agency (EPA) cloud tracking efforts. The EPA fielded two Turbo Beech aircraft for cloud sampling. A Martin 404 (the NATS cloud tracking aircraft) was on standby at McCarran Airport in Las Vegas, Nevada.

8.2.3 Construction and Experiment Readiness

A. Satellite Drill Hole

Early in the planning phase, during May 1970, a proposal was made to drill and instrument a satellite hole located 22 feet west of the U1lg emplacement hole. It was proposed that, during drilling operations, measurements be made to determine the density, porosity, water content, sound velocity, and chemical composition of cores taken at depths of 660-670, 835-845, and 860-870 feet. Upon completion of drilling, it was planned to measure density, sound velocity, and resistivity (for water content) in the hole. It also was proposed that instrumentation be placed in the satellite hole to determine ground shock pressure-time history following device detonation. Drilling began on 23 June and was completed on 10 July 1970. No problems were encountered.

B. Mobile Tower

The majority of the experiments were housed on a mobile tower. One experiment fielded by LLL was installed in a skid adjacent to the tower, and a limited number of experiments were installed in a diagnostics spool located in the LOS pipe. The tractor tread base of the mobile tower was first used on NEW POINT (Operation LATCHKEY) with a multi-story tower installed. For MILK SHAKE (Operation CROSSTIE), the tower was removed and a new experiment room (house) was installed on the base. This house, with slight modifications, was used on MINUTE STEAK and DIAGONAL LINE. A diagnostics tower was mounted on top of the house. In order to move the tower away from SGZ after zero time, but before subsidence crater formation, two winches were located 605 feet west of SGZ and were connected by two steel cables to the base of the mobile tower. It was planned to start the winches at H+10 seconds and to move the mobile tower 300 feet to the west within three minutes. The Test Group Director controlled activation of the winches from CP-1, by means of either microwave or hardware communications.

C. Emplacement Hole Preparations

The U1lg preemplacement hole was drilled during the latter part of 1968 as part of a program to economically provide drill holes for future tests. It was not specifically drilled for the DIAGONAL LINE event. Site preparation began 24 September 1968 and drilling started 15 November 1968. The preemplacement hole was completed including casing, grouting, measurements, and surveys on 20 December 1968.

The U1lg drill hole was formally selected for DIAGONAL LINE in early 1970. Site construction began in May 1970. In November 1970, the concrete was poured for the pit. On 9 November 1970, the "Containment Plan for DIAGONAL LINE" was forwarded to AEC/NVOO for consideration by the

Test Evaluation Panel (TEP). On 23 November 1970, LLL made available to Test Command an internal LLL memorandum dated 23 December 1969 which impacted the planned downhole operations markedly. This memorandum de-rated all NTS cranes to two-thirds the manufacturer's rated capacity when handling LLL nuclear devices. This automatically prohibited use of the 4600 Manitowoc crane in the manner in which it was scheduled to be used for final downhole operations. There appeared three options available to Test Command for a crane "suitable" to meet LLL criteria:

1. Modify the already completed SGZ pit and the already delivered three top sections of pipe to permit the originally scheduled crane to be used;

2. Use the one 4600 Manitowoc, "Ringer" crane which had been modified to lift heavier loads; or

3. Obtain the use of an "offsite" rental crane capable of handling the device canister and VLOS pipe with LLL's de-rated criteria.

Option 3 was selected since Option 1 presented an unacceptable delay to modify the VLOS pipe, and the crane cited in Option 2 was already scheduled for an LLL event during the period it would be required for DIAGONAL LINE.

The planned VLOS downhole dry run was delayed from 4 to 11 January 1971 to allow for the installation and testing of a "dead man" switch on the rental crane. This requirement, by REECo Industrial Safety, was generated after the crane was rented without such a switch. Downhole operations were further delayed until 13 January

1971 because the H&N inspectors were not present to certify testing of the switch under full load on the first test. It was noted at that time that the rented crane did not have a power down capability, a feature LLL required of all cranes handling their devices in downhole operations. It was planned to use the crane "as configured" for the dry run, then reconfigure it with the power down capability between the conclusion of the uphole operations and the final downhole run.

On 13 January 1971, the VLOS pipe system downhole dry run began. The downhole operation was completed on 16 January and the mobile tower was moved over the emplacement hole. After alignment checks were completed, the mobile tower was pulled from its position over the hole to a position 300 feet west of SGZ as a dry run of the winch system.

On 17 January, a drill rig was moved over the satellite hole and water was bailed from the hole to a depth of 873 feet. Diagnostic instrumentation packages were attached to a fiberglass pipe and lowered into position in the satellite hole. Following instrumentation installation, the hole was stemmed.

During the period 21-26 January, the closures in the LOS pipe were tested and the pipe sections were removed from the hole and placed in readiness for the final downhole operation. Also during this period, 698 instrumentation cables were turned over to the experimenters. There were 22 instrument trailers in the park located 830 feet west of SGZ. These trailers were equipped with tape recorders and oscilloscopes with cameras for recording data. Instrumentation in the trailers was designed to be remotely activated by timing signals from the control room at CP-1.

In March, information was received that the performance of the BANEBERRY event had necessitated revisions in the review procedures by the AEC TEP and that execution authority for DIAGONAL LINE would be delayed. The site was placed in standby status on 12 March. On 17 March 1971, Test Command submitted an addendum to the containment plan previously submitted. This addendum provided for an additional cable gas block.

On 1 April, the AEC/NVOO Containment Evaluation Panel (the TEP had been revised in membership and renamed) requested additional geological information. In order to obtain this information, an exploratory drill hole had to be drilled. Drilling operations began on 19 April and were completed on 21 May. Based on all available information, DNA forwarded the final containment plan to AEC/NVOO for use by the CEP at the 21 May meeting. The plan was accepted as presented. The hole was stemmed to the surface in late July.

On 23 August, the site was reactivated. Experimenters and construction personnel returned to work. Signal dry runs were conducted and a successful mandatory full participation dry run was conducted on 8 September. LOS pipe downhole operations began the following day and were completed on 20 September. An alignment check of the DIAGONAL LINE LOS pipe system was conducted on 20 September 1971, and alignment of the system was found to be satisfactory. Vacuum pumps were activated and the vacuum integrity of the LOS pipe system below the fast gate was verified. The emplacement hole was stemmed during the period 21 to 30 September. The closure system, slide valve, and LLL diagnostics spool were installed in early October. The mobile tower was moved over the LOS pipe and aligned. At this point the event was placed in a hold status from 8 October until 1 November awaiting test execution authority. After receiving test execution authority, event execution was further delayed from 15 to 22 November due to unfavorable wind conditions.

8.2.4 Late Pre-event Activities

DIAGONAL LINE was originally scheduled for 16 November 1971. On 14 November, the event was at D-2 readiness posture. From 15 November to 23 November, the event was maintained at D-1 readiness level due to high winds.

Following the readiness briefing 1430 hours on 23 November, the decision was made to button up the test area and try for execution on 24 November. The mobile tower and instrumentation trailer park were secured in accordance with a button up check list prepared and rehearsed earlier. A readiness briefing was conducted at 2100 hours. Predicted winds appeared to be favorable for a 24 November test execution. Security sweeps were conducted.

8.3 EVENT-DAY AND CONTINUING ACTIVITIES

A readiness briefing was conducted at CP-1 at 0730 hours. Winds were still predicted to be from the southwest and a scheduled detonation time of 1000 hours was set. Shortly before 1000 hours, a one-hour hold was called to deal with a technical problem, and to wait for southerly winds. At 1030 hours, scheduled detonation was delayed until 1130 hours, again due to unfavorable winds.

The DIAGONAL LINE device was detonated at 1215 hours PST on 24 November 1971.

8.3.1 Test Area Monitoring

Telemetry measurements began at 1216 hours. All RAMS units in the array indicated radioactivity which was attributed to activation of materials contained in the tower. The maximum reading detected was 40 R/h at H+1 minute by unit No. 2 (located at SGZ) which then went off line at H+15 minutes when the crater formation began. Crater formation did not occur in a typically uniform rapid collapse. It proceeded in stages or steps taking about three minutes to reach its full shape. In the collapse process, the SGZ pit was rotated and came to rest at a point 25 feet inside the east wall. Closed circuit television monitors showed that the crater was not symmetrical around SGZ and that it was steep-walled. It was elliptical in shape, measuring 180 feet by 210 feet, and the axis was oriented on a northeast-southwest line. The crater was estimated to be 56 feet deep at its deepest point. RAMS units showed normal LOS activation product decay until about 1530 hours when a seepage of radioactive effluent from the SGZ pit began; readings from unit No. 5 to the northeast of SGZ began to increase, reaching a maximum of 90 mR/h at about 1630 hours. By 1630 hours, all initial trailer park surveys, recovery operations, and crater surveys had been completed. For further discussion on these activities, see section 8.3.2.

Following reentry and recovery operations, an attempt was made to confine the radioactive effluent by pumping 1,200 cubic feet of Cal-Seal into the SGZ pit. This was unsuccessful because the sealant flowed out of the northwest corner of the inclined pit. Because Cal-Seal could not be placed near SGZ due to the sloping ground surface, further attempts to seal the slow seep were discontinued. Although low level seepage in the immediate area of the SGZ pit was detectable for several days, the release associated with DIAGONAL LINE was essentially complete by H+20 hours.

At about 1700 hours, a reading of 150 mR/h was recorded on unit No. 7 to the southeast of SGZ. This was the highest reading recorded until shortly after midnight when unit No. 9, located southwest of SGZ also recorded a reading of 150 mR/h. A permanent RAMS unit at well 5B (5 miles south of SGZ) indicated 6.6 mR/h at about 2230 hours returning soon thereafter to background. From shortly after midnight on, the overall readings declined. By 1000 hours on 25 November all perimeter RAMS were reading less than 1 mR/h. The effluent was rare gases and radioiodines. Calculated total curies at time of release was 21,000 and at H+12 was 6,800. Transport of the released gas was generally toward the northeast about 5 miles per hour from the beginning of release until approximately 1630 hours when it shifted toward the east and then toward the south by about 1800 hours. Transport remained generally toward the south during the night, but there were periods when local SGZ winds became variable. At times, nearly all RAMS units indicated some radioactivity. Telemetry was secured at 1516 hours on 3 December 1971. Air samplers were secured at the same time.

8.3.2 Initial Radiation Survey and Experiment Recovery Activities

Initial radiation survey teams dressed in anticontamination clothing and respiratory protection equipment were released to enter the controlled area by the Test Manager at 1316 hours. The survey was completed at 1415 hours with a maximum reading of 6 mR/h being obtained approximately 25 feet from the tower at 1326 hours. No alpha radiation was detected.

After the trailer park was determined to be safe for reentry, experimenters (also dressed out) were allowed to enter the area at 1350 hours to recover data, film, and magnetic tapes. The maximum reading obtained during these data recovery operations was 1.3 R/h inside the tower at 1543 hours on 24 November.

All cleanup and photography personnel were out of the tower at 1530 hours, and this data recovery was completed at 1630 hours.

The initial crater survey was performed at about 1445 hours and was negative for both carbon monoxide and carbon dioxide. Additional scheduled surveys around the crater on D-day were cancelled by the Test Manager because of the steep sides and asymmetry of the crater. Radiation surveys were reestablished on D+1 and were conducted twice per shift until 30 November. All measurements for carbon monoxide and carbon dioxide were negative.

8.4 POSTEVENT ACTIVITIES

8.4.1 Environmental Protection Agency Offsite Surveillance Activities

The Western Environmental Research Laboratory/EPA was notified of the radioactive effluent seepage at 0745 hours on 25 November, and also was notified that an EG&G aircraft had detected the radioactive effluent offsite that morning in the Lathrop Wells and Ash Meadows area. EPA monitors were then deployed to areas southwest of the NTS. Charcoal cartridges were added at the EPA Air Surveillance Network (ASN) stations at Pahrump, Nevada; and Shoshone, and Furnace Creek, California. In addition, the standby ASN stations at Spring Meadows Farms and the Amargosa Farm area, Nevada, were activated. For EPA analysis, air particulate filter and charcoal cartridge samples were collected from the following stations and times with no results above background and returned to the EPA for analysis as shown in Table 10.

On 25 November, Monitoring personnel took survey instrument readings along the roads shown in Table 11.

Table 10. Air particulate filter and charcoal cartridge sample result locations.

Location	Date Collected	Sampling Day/Time	Period Day/Time	Sample Type*	PF Count Time/Date
Indian	11/25/71	25/0700	25/1345	PF, CC	1508 11/25
Springs, NV	11/26/71	25/1345	26/0600	PF, CC	1037 11/26
Lathrop Wells, NV	11/26/71	25/0630	26/0700	PF, CC	1047 11/26
Pahrump, NV	11/25/71	24/1350	25/1100	PF, CC	1823 11/25
	11/26/71	25/1110	26/0630	PF, CC	1050 11/26
Shoshone, CA	11/25/71	25/0925	25/1615	PF, CC	1817 11/25
	11/26/71	25/1620	26/0710	PF, CC	1056 11/26
Furnace Creek, CA	11/26/71	25/1000	25/1620	PF, CC	1449 11/26
Death Valley	11/25/71	25/0915	25/1530	PF, CC	1812 11/25
Junction, CA	11/26/71	25/1530	26/0715	PF, CC	1045 11/26
Spring Meadows**	11/26/71	25/1320	26/0800	PF, CC	1053 11/26
Amargosa Farms**	11/26/71	25/1430	26/0830	PF, CC	1039 11/26

*PF = Particulate filter
CC = Charcoal cartridge
**Standby Air Surveillance Network Station

Table 11. Roads monitored by EPA personnel.

Roads Monitored	Time
Highway 95; Indian Springs, NV, to 10 miles NW of Lathrop Wells, NV	1000 to 1515
Highway 52; Pahrump, NV, to Ash Meadows turnoff	1130 to 1150
Ash Meadows turnoff to Ash Meadows, NV	1150 to 1300
Ash Meadows, NV, to Springs Meadows Farms, NV	1300 to 1320
Springs Meadows Farms, NV, to Highway 29 turnoff	1335 to 1345
Highway 29; Amargosa Farm Area, NV, to Shoshone, CA	1345 to 1600

No radioactivity above normal background levels was detected by the gamma rate recorder network. No air particulate samples contained gross beta activity above normal background levels, and no event-related activity was detected on air particulate filters or charcoal cartridges. No special water, milk, or other environmental samples were collected for this event.

8.4.2 Experiment Recovery Activities

The trailer park and tower were opened for additional experiment recoveries on 29 November, after approximately 125 smears had been taken by Radsafe personnel; all showed negative results. These recoveries were performed without anticontamination clothing or respiratory protection equipment being worn.

From 29 November to 2 December, experiment recovery operations proceeded at a rapid pace. By 2 December, a majority of the experiments had been removed, packaged, and shipped to the parent organizations.

In addition, on 26 November, monitoring personnel took survey instrument readings all of which were background at the locations shown in Table 12.

8.4.3 Crater Survey

On 7 December, a road was prepared which permitted access into the crater so that a survey could be performed. This survey disclosed a 3-1/2 to 4-inch diameter hole next to the pit, almost due west of SGZ. Radiation readings in the hole were 0.7 mR/h. The Sandia health physicist requested carbon monoxide and carbon dioxide samples, and a soil sample from inside the hole. Soil sample analysis indicated the presence of iodine-133 and xenon-133. Gas sampling inside the hole indicated xenon-133 and -133m; and Draeger tubes measured 400 ppm carbon monoxide and no carbon dioxide.

Table 12. EPA survey instrument reading locations.

Location	Time
Indian Springs, NV	0600
Highway 95; Mercury turnoff	0630
Lathrop Wells, NV	0715
Junction Highway 29/Springs Meadows Road	0745
Spring Meadows, NV	0800
Junction Highway 29/Amargosa Farm Road	0820
Dansby Ranch, Amargosa Farm Area, NV	0830
Pahrump, NV	0550
Shoshone, CA	0630
Death Valley Junction, CA	0730
Furnace Creek, CA	1145

Recovery of the instrumentation spool, slide valve, closure system and vacuum pump from the SGZ pit was performed without incident between 13 and 17 December 1971. The site was returned to the AEC Test Manager on 6 January 1972.

8.4.4 Industrial Safety

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224).
2. AEC Manual 500 Series for the Nevada Test Site.
3. Individual Safe Operating Procedures (by experimenter organizations).
4. DIAGONAL LINE Safety Regulations.

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of these operations) were required to wear safety glasses or other eye protection which had been approved by the DOD Safety Coordinator.

The area enclosed by the U1lg fence was designated a hard hat area. Hard hats were required to be worn and foot protection in the form of safety boots, safety shoes, or toe guards was strongly recommended.

A written standard operating procedure was required for each operation involving materials or any operation with potential for personal injury. Each individual involved in a project was required to be knowledgeable regarding applicable procedures for their project.

Checks were made on each shift for radiation levels, toxic gases, and explosive mixtures. These measurements were then recorded in the monitors' log book. The maximum concentrations of toxic gases detected during DIAGONAL LINE operations were:

1. 400 ppm carbon monoxide on 7 December as a result of gas sampling (Draeger tubes) inside the hole next to the SGZ pit.

2. 400 ppm carbon monoxide on 7 December on the east side of the SGZ pit under the concrete overhang.

3. 400 ppm carbon dioxide on 20 December inside the LOS pipe.

No explosive mixtures were detected.

Industrial safety codes, including specific codes for drilling, were established by REECo and were emphasized during all operations.

8.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1216 hours on 24 November 1971. The maximum exposure rate detected was 40 R/h at RAMS unit No. 2 located at SGZ. This measurement was obtained at H+1 minute on D-day and was due to experiment activation. RAMS unit No. 2 went off line at H+15 minutes on 24 November 1971. The first indication of seepage was detected by RAMS units Nos. 3, 5, and 6 at 1414 hours on D-day. Telemetry was secured at 1516 hours on 3 December 1971.

The initial reentry survey began at 1316 hours and ended at 1415 hours on D-day. The maximum gamma exposure rate detected was 6 mR/h at approximately 25 feet from the tower. No alpha radiation was detected. The maximum gamma exposure rate detected during recovery operations was 1.3 R/h inside the tower in the main area at 1543 hours on 24 November 1971. A drillback was not performed.

The maximum concentrations of carbon monoxide detected during the entire operation were 400 ppm on 7 December 1971 on the east side of the SGZ pit under the concrete overhang; and 400 ppm on 7 December as a result of gas sampling inside the hole next to the SGZ pit. A reading of 400 ppm carbon dioxide was detected inside the LOS pipe at 0915 hours on 20 December 1971. No explosive mixtures were detected.

There were no whole body external or internal organ exposures which exceeded the guides.

Personnel exposures received during individual entries to the DIAGONAL LINE event from 24 November 1971 to 28 November 1971 when Area Access Registers were discontinued are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	163	30*	0
DOD Participants	55	0	0

*Minimum detectable gamma exposure with NTS film dosimeter is 30 mR per film pocket worn.

CHAPTER 9

MISTY NORTH EVENT

9.1 EVENT SUMMARY

The MISTY NORTH device was detonated with a yield less than 20 kt at 1215 hours PDT on 2 May 1972. The LASL-provided device was emplaced in tunnel U12n.05 at a vertical depth of 1,234 feet (Figure 33). The objective of this weapons effects detonation was to investigate the response of materials and equipment to a nuclear detonation environment. Government agencies and contractors conducted 45 projects to obtain the desired information. Containment of the MISTY NORTH event was complete.

9.2 PRE-EVENT ACTIVITIES

9.2.1 Responsibilities

AEC and AEC contractor responsibilities were in accordance with established AEC/DOD agreements or were the subject of separate action between Test Directorate, FC/DNA and the AEC Nevada Operations Office. Reentry and recovery safety programs were conducted by SLA.

The LASL Test Group Director was responsible to the Test Manager for radiological safety within a 6,000-foot radius of SGZ. This responsibility was in effect from the time the device was moved to the emplacement site until device detonation. At that time, the LASL Test Group Director was relieved of responsibility and it was delegated to the DNA Test Group Director.

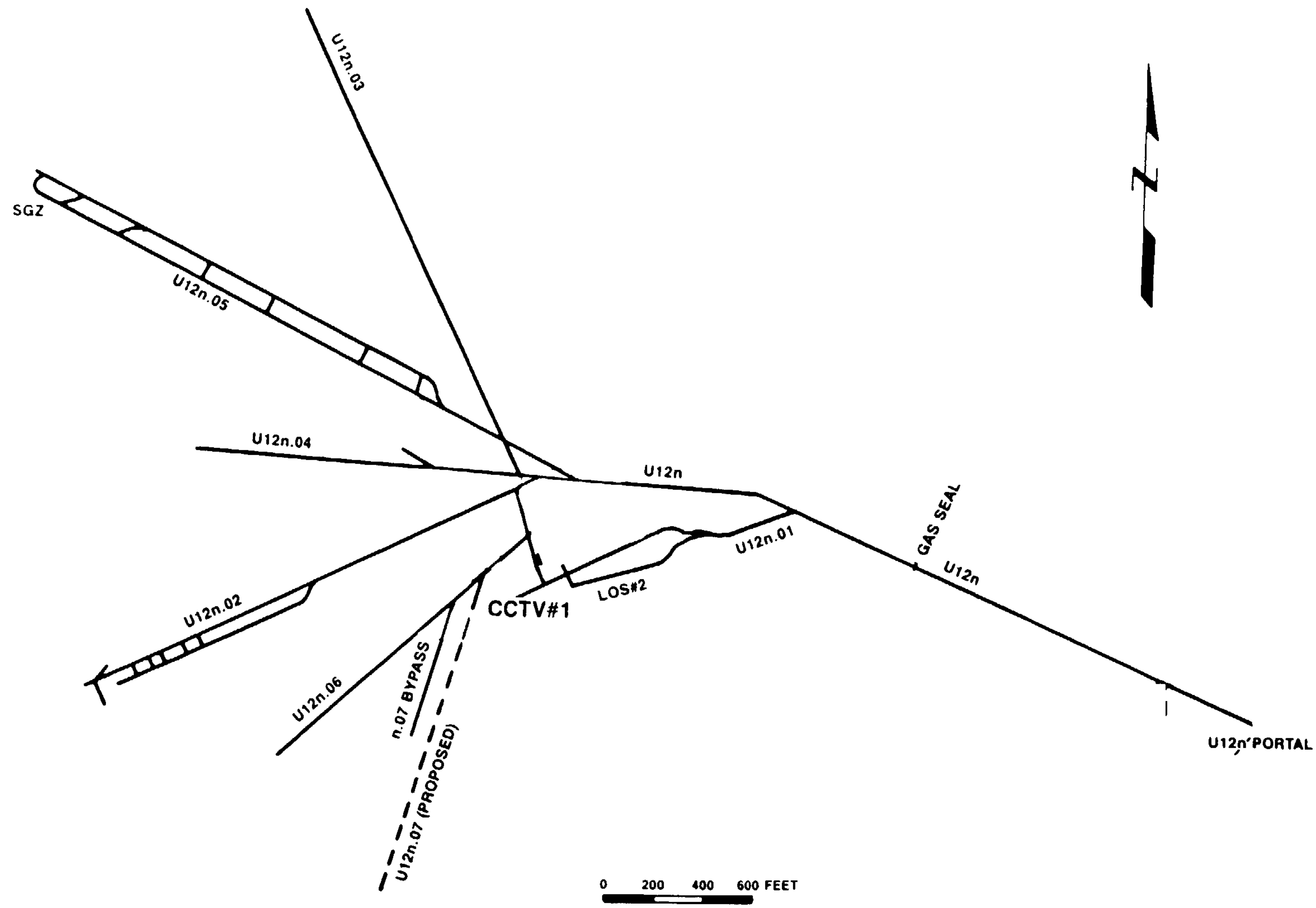

Figure 33. MISTY NORTH Event tunnel layout.

9.2.2 Planning and Preparations

A. Tunnel Facilities Construction

Preparation of the portal and Mesa facilities and mining of the 05 drift began on 1 December 1970 and was virtually completed by early November 1971. Early in the mining program some interference was experienced due to the necessity for all personnel entering Area 12 to dress out in full radex gear because of radioactive effluent produced when the BANEBERRY event vented to the atmosphere on 18 December 1970. Another outcome of the BANEBERRY event was the initiation of more extensive area clearing procedures. These new procedures required all personnel to be cleared from all forward areas prior to each event. Prior to BANEBERRY, Area 12 mining personnel were allowed to travel through the west portion of Yucca Flat to their work location, while east portions of the Yucca Test area were cleared and events were executed in those locations.

Mining of the 05 drift allowed many facilities previously installed for MIDI MIST, HUDSON SEAL, and DIANA MIST to be reused. Among these facilities were the gas seal door, the downhole cable alcove, three downhole cable runs from the Mesa trailer park to the cable alcove, and the trailer park and portal facilities. Additional facilities required for MISTY NORTH were the 2,600-foot experimental and bypass drifts, the overburden plug, a gas seal plug between the overburden plug and the gas seal door, a red shack, and concrete gas blocking plugs on the Mesa for cables in each of the three downhole cable runs. This was the first time gas blocks were used in the overburden plug.

A bypass drift and crosscuts were mined to (1) allow early initiation of pipe installation (prior to completion of mining in the experiment drift), (2) reduce the tunnel traffic in the experiment drift, (3) provide a suitable location and easy installation of instrument cables, and (4) allow late-time installation of the Sandia Auxiliary Closure (SAC). Crosscuts between the experiment drift and bypass drift at the experiment stations provided alcove space which was used by experimenters for housing power supplies, signal conditioning equipment, and experiment preparation working space.

As on previous events, countdown functions for the unmanned trailer park and tunnel were controlled from CP-1. These signals were routed via microwave and hardwire to a timing and firing trailer in the Mesa trailer park. Critical functions in the tunnel and instrumentation trailers were monitored at CP-1 in the LASL control room (device functions) and the DOD monitor room (experiment functions).

A multiplex system was installed to control and monitor reentry ventilation valves, fans, and electrical power distribution systems. This system employed two similar control panels, one at the tunnel portal and one at the DOD monitor room at CP-1. A gas sampling system was installed so that samples could be drawn remotely from inside the gas seal door or from the zero point side of the gas seal plug and overburden plug. The gases could be analyzed for radioactivity and explosive mixtures, and then returned inside the gas seal plug if required. The gas sampling system also was capable of being operated manually at all points during manned tunnel reentry.

The fielding period began with the Test Group Staff (TGS) moving to the NTS early in January 1972. Installation of all experiments was complete on 2 March, and a successful signal dry run was held on the same day. Signal dry runs continued to be conducted throughout the preevent period.

A successful dry run was held on 6 April 1972, and the device was emplaced on 10 April 1972. After a series of delays, the final dry run was held at 1300 hours on 1 May 1972 with no problems.

B. Radiological Safety Support

Detailed support plans were prepared jointly by REECo Radsafe representatives and representatives of DNA. These included but were not limited to the "Field Operations Support Plan" and the "Detailed Safety Support Plan." Procedures for radiation exposure and contamination control were in accordance with requirements of responsible DOD and SLA personnel. Radsafe provided monitoring and equipment support, air sampling, and telemetry. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

A geophone system was used to monitor postevent seismic disturbances from rock fall preceding and during cavity collapse. Signals were routed to CP-1 for audible and recorded readout.

All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance. Anticontamination equipment and materials available included coveralls, headcovers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

One base station with a team of Radsafe monitors was positioned at the FCP. This station was used to "suit up" the surface reentry and recovery parties before their departure from the FCP. If contamination was encountered, this station would then be used to monitor and decontaminate personnel and equipment as they returned from the controlled area.

C. Telemetry and Air Sampling Support

RAMS units for the MISTY NORTH event were located as shown in Table 13 and Figures 34, 35. Underground units were installed on 27 April and calibrated on 28 April. Surface units were installed on 29 April and calibrated on 30 April. The MISTY NORTH telemetry system was event-ready on 2 May.

D. Security Coverage

Device security coverage was in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." All persons entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges, or issue and return of muster badges. After area control was established, all through traffic was diverted by use of screening stations.

In accordance with the "Test Manager's Operations Plan," contractors and agencies were to have all personnel not

Table 13. MISTY NORTH Event RAMS unit locations.

Station	Location
	SURFACE
1	At portal
2	Vent line filter system
3	Vent line filter system
4	Vent line filter system
5	64 feet at S 28° E azimuth from portal
6	400 feet at N 16° E azimuth from portal
7	275 feet at N 89° E azimuth from portal
8	363 feet at S 16° E azimuth from portal
9	482 feet at S 12° W azimuth from portal
10	558 feet at S 48° W azimuth from portal
11	416 feet at N 69° W azimuth from portal
12	648 feet at N 27° W azimuth from portal
13	1,316 feet at N 20° E azimuth from portal
14	1,368 feet at S 43° E azimuth from portal
15	2,773 feet at S 54° W azimuth from portal
16	2,766 feet at N 44° W azimuth from portal
17	At downhole cable hole
18	180 feet at N 45° E azimuth from downhole cable hole
19	145 feet at S 35° E azimuth from downhole cable hole
20	336 feet at S 13° E azimuth from downhole cable hole
21	670 feet at S 28° W azimuth from downhole cable hole
22	370 feet at S 30° W azimuth from downhole cable hole
23	70 feet at N 88° W azimuth from downhole cable hole

Table 13. (Concluded)

Station	Location
	SURFACE (Continued)
24	280 feet at N 04° W azimuth from SGZ
25	405 feet at S 34° E azimuth from SGZ
26	560 feet at S 41° W azimuth from SGZ
	UNDERGROUND
31	1,800 feet into the U12n.05 main drift
32	1,480 feet into the U12n.05 bypass drift
33	1,496 feet into the U12n.05 main drift
34	1,040 feet into the U12n.05 bypass drift
35	1,043 feet into the U12n.05 main drift
36ER*	675 feet into the U12n.05 main drift
37	675 feet into the U12n.05 main drift
38	522 feet into the U12n.05 main drift
39	3,280 feet into the U12n main drift
40	3,004 feet into the U12n main drift
41	2,546 feet into the U12n main drift
42ER*	1,617 feet into the U12n main drift
43	1,617 feet into the U12n main drift
44	1,475 feet into the U12n main drift
45	900 feet into the U12n main drift
46	50 feet at vent line rise
47	200 feet into the U12n main drift

*Extended range

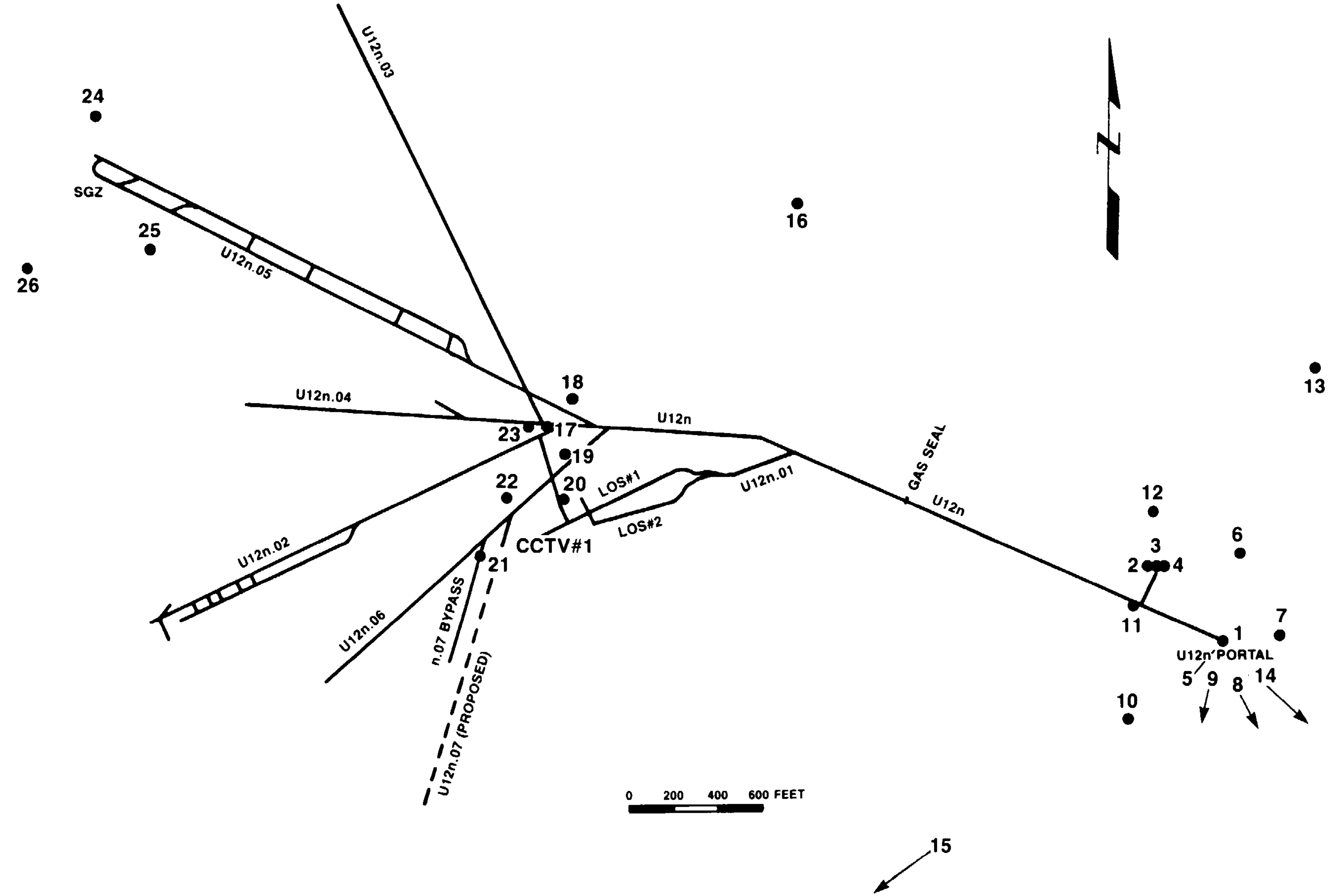

Figure 34. MISTY NORTH surface RAMS unit locations.

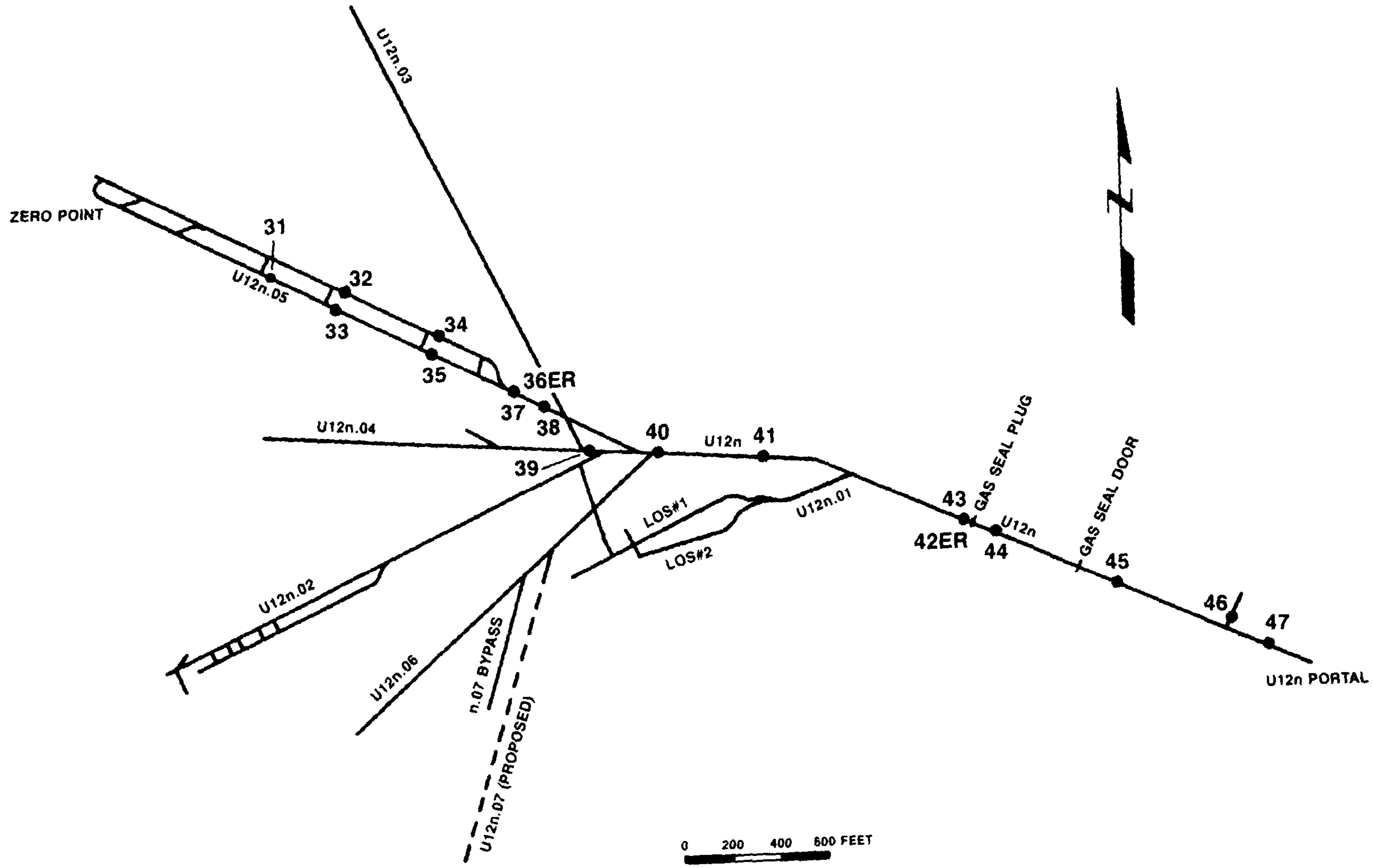

Figure 35. MISTY NORTH underground RAMS unit locations.

connected with this event out of the controlled area before the final security sweep began.

E. Air Support

One UH-1N helicopter and one UH-1F helicopter with crews were provided by the U.S. Air Force for security sweeps and closed circuit television coverage support needed by Aerospace Audio Visual Services (AAVS) personnel. Another USAF UH-1N helicopter and crew were provided to perform cloud tracking if needed; otherwise it was on standby for the Test Controller. The EPA fielded a Turbo Beech aircraft for cloud sampling and had another Turbo Beech on standby at McCarran Airport in Las Vegas, Nevada. A Martin 404 (the NATS cloud tracking aircraft) also was on standby at McCarran Airport.

9.2.3 Late Pre-event Activities

Button up activities were performed by personnel representing SLA, EG&G, Kaman Sciences Corporation (KSC), PI, Systems Science and Software (SSS), ETI, GA, AVCO, AFWL, LASL, Boeing, LMSC, and the Navy. The first security sweeps began during the late evening hours.

9.3 EVENT-DAY AND CONTINUING ACTIVITIES

Security sweeps were conducted as scheduled from 0045 until 0800 hours. The muster station was relocated to Gate 300 at 0500 hours and the closed area was clear of all personnel except for the arming party, its support crew, and authorized manned station personnel. Any other personnel requiring access were required to have specific approval from the Test Manager and concurrence from the Test Group Director. Following favorable recommendations at the readiness briefing at 0500 hours, permission to arm the device was given at 0730 hours. Final security sweeps which had been going on simultaneously with the readiness briefing were completed at 0800 hours. At that time, confirmation was received from all manned stations that all personnel were at their stations and accounted for and that communication and transportation were sufficient. This confirmation process was repeated at 0830 hours.

A detonation time of 1000 hours had been agreed upon at the readiness briefing at 0500 hours. All predetonation activities proceeded as scheduled until 0945 hours when a one-hour delay was called due to technical problems. Another technical problem at 1051 hours caused an additional delay. This problem was resolved, and the fifteen-minute countdown began at 1200 hours.

MISTY NORTH was detonated at 1215 hours PDT on 2 May 1972.

9.3.1 Test Area Monitoring

Telemetry measurements began at 1216 hours. All units were operational except for unit No. 31 which was off line due to cable loss at zero time. Unit No. 33 measured 3.5 R/h at H+1 minute. This was the maximum reading for this event. RAMS units detected normal neutron activation radioactivity which decayed rapidly to background levels. Telemetry was discontinued at 1600 hours on 10 May 1972.

9.3.2 Initial Surface Radiation Surveys and Experiment Recovery Activities

At 1316 hours, the initial surface radiation survey party was cleared to go as far as 8-01 Road (4.1 miles southeast of the U12n portal) where WSI was to activate a roadblock. At 1415 hours, team Nos. 1 and 2 were cleared to proceed to the Mesa trailer park and team Nos. 3 and 4 proceeded to the portal area. The portal survey was completed at 1443 hours and the Mesa survey at 1520 hours. Only background radiation levels were measured.

Experimenters began operations to recover data from the trailer park at about 1527 hours. All experimenters had departed the controlled area at 1915 hours.

The tunnel ventilation system was turned on at 1745 to ventilate the tunnel on the portal side of the gas seal door.

9.4 POSTEVENT ACTIVITIES

9.4.1 Tunnel Reentry and Experiment Recovery Activities

An initial tunnel reentry team (dressed in anticontamination clothing and Scott-Draeger respiratory protection equipment) entered the portal at 1005 hours and reached the gas seal door at 1012 hours on 3 May 1972. Some minor rock spalling was noted along the track, but no problems were encountered. The manway through the gas seal door was opened at 1026 hours, as well as the portal side drain valve. No toxic gases or explosive mixtures were detected. The team continued on into the tunnel, reaching the 300 psi plug at 1040 hours. The radiation level detected through the plug was 0.1 mR/h. By 1230 hours, the large gas seal door was opened. The team returned to the portal at 1320 hours. Another team entered the tunnel at 1350 hours to establish communications at the gas seal door, complete vent line work, and establish a compressed air line through the 300 psi plug. In addition, the team installed the railroad tracks through the gas seal door. This team exited the tunnel at 1551 hours.

On 4 May, gas sampling on the zero point side of the overburden plug indicated that tunnel atmosphere conditions were good. However, the vent line was later found to be broken allowing outside air to be sampled rather than the tunnel atmosphere. Reentry activities proceeded routinely and, at 0940 hours, the team boarded the train to check out the remainder of the tunnel complex. The team returned to the portal at 1150 hours.

Reentry team members left the portal at 0906 hours on 5 May and proceeded to the gas seal door where team members established communications. They then departed by train, reporting that 03 and 04 drifts were in good condition. Team members reached the overburden plug at 1039 hours; there was good air flow through the overburden plug manway. Only background radiation readings were obtained, and no water was apparent through the plug. Continuing into the bypass drift (Figure 36), crosscut No. ES-1 was in good condition; consequently, team members removed the sandbags, checked the radiation level (background), and entered the LOS pipe drift to check test chamber No. 1. Team members exited the pipe drift at 1215 and were back at the portal at 1244 hours.

A second team departed the portal for the overburden plug at 1330 hours. Team members continued on to the LOS pipe drift and checked out crosscut No. 2, which did not appear to be safe for reentry. They did remove the sandbags, however. The team went on and checked out the pipe toward ES-3, test chamber No. 2, and AES-1. It was evident to team members that the entire drift beyond crosscut No. 2 was in bad shape. They exited the tunnel complex at 1615 hours and reentries were subsequently terminated for the day. All readings inside and outside the LOS pipe were background.

On 8 May, a reentry team entered the tunnel complex and traveled to AES-1 (not shown on Figure 36), ES-1, and ES-2. The vent line was in good condition up to ES-2. After this walkthrough, the Scientific Assessment Team entered the tunnel

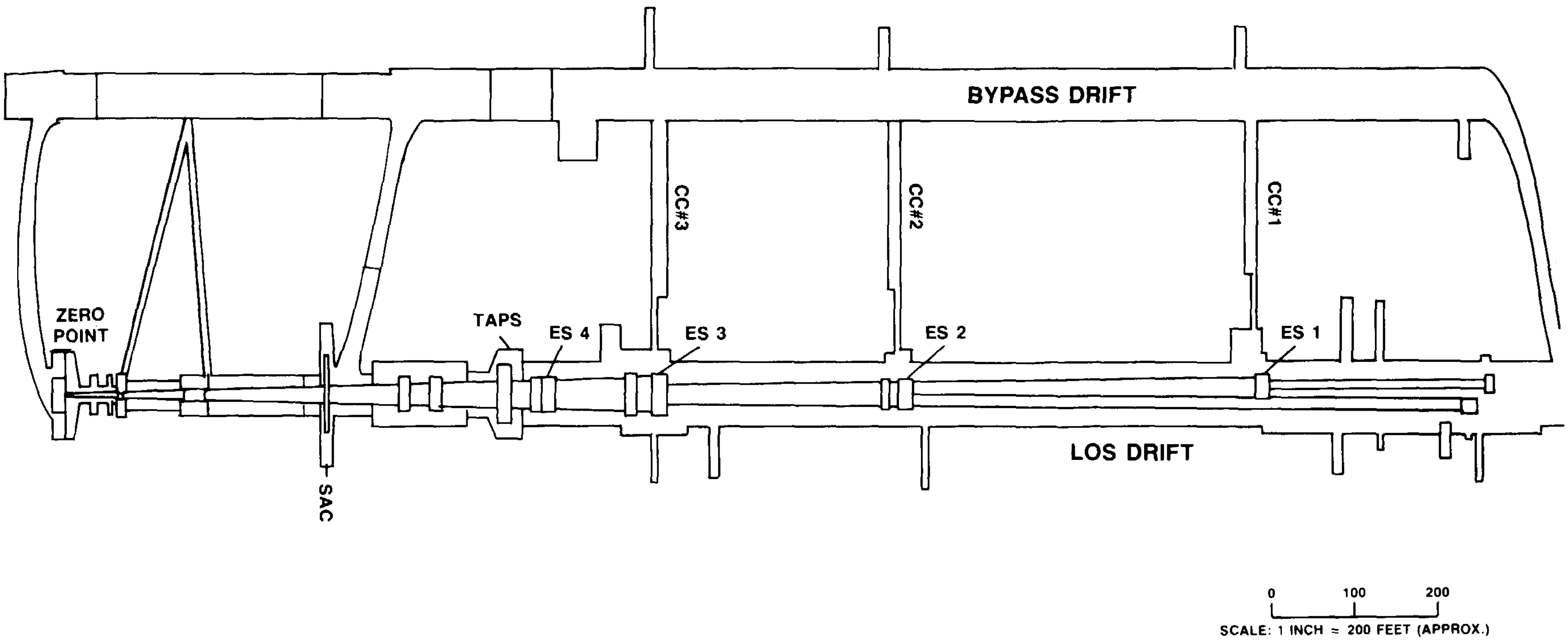

Figure 36. MISTY NORTH Event LOS and bypass drifts.

complex to assess the condition of experiments and perform station photography at AES-1, ES-1, and ES-2.

9.4.2 Postevent Mining and Experiment Recovery Activities

Mining through the gas seal plug and overburden plug began on 10 May. This operation was successfully completed the same day. The tunnel was opened for experiment recovery on 11 May. Experiments from ES-1, ES-2, AES-1, and AES-3 were all recovered by 12 May. A reentry drift for experiment recovery into ES-3 and ES-4 was started on 15 May. After mining 114 feet of this drift, the ground became so unstable that reentry drift mining was abandoned and rehabilitation of the 05 bypass drift was initiated as the new reentry path. Rehabilitation was completed on 1 June.

Examination of the LOS pipe between ES-3 and ES-4 revealed that it was safe to recover experiments from ES-4 by walking through the pipe. All personnel performing experiment recovery operations inside the LOS pipe were dressed in anticontamination clothing and respiratory protection equipment. All experiments from ES-3 and ES-4 were recovered by 5 and 6 June, respectively.

Work to reach the SAC (for purposes of evaluation only) began on 7 June and was successfully concluded on 1 August 1972.

9.4.3 Industrial Safety

The portal construction area and the tunnel were hard hat and foot protection areas. Each participating agency provided its own industrial safety equipment. All personnel on the initial tunnel reentry teams were certified in the use of the McCaa 2-hour breathing apparatus and had used the Scott-Draeger self-contained breathing apparatus. Standard safety rules and practices, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

All explosives, electro-explosive components, solid propellants, toxic material, and radioactive material were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Materiel Command Regulations (AMCR 385-224)
2. AEC Manual 500 Series for the Nevada Test Site
3. Individual Safe Operating Procedures (by experimenter organization)
4. MISTY NORTH Safety Regulations

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DOE Safety Coordinator.

Checks were made during each shift for toxic gases and explosive mixtures. These measurements were recorded in the monitor's log book. Industrial safety codes, including specific codes for mining and drilling, were established by REECo and were emphasized during all operations.

9.5 RESULTS AND CONCLUSIONS

Telemetry measurements were taken between 1216 hours on D-day and 1600 hours on 10 May 1972. The maximum reading of 3.5 R/h was measured at underground station No. 33 at 1217 hours on D-day.

Both portal and Mesa surveys were conducted between 1415 and 1520 hours on D-day. Only background radiation levels were measured.

An initial tunnel reentry was conducted between 1005 and 1320 hours on 3 May 1972. The maximum radiation reading measured was 0.1 mR/h at 1040 hours at the gas seal door.

Postevent mining to recover experiments and evaluate the Sandia Auxiliary Closure was conducted between 10 May and 1 August 1972. No radiation, toxic gas, or explosive mixture problems were encountered.

No whole body external or internal organ exposures in excess of exposure guides were received during MISTY NORTH operations.

Personnel exposures received during individual entries to the MISTY NORTH event from 2 May 1972 to 12 July 1972 when Area Access Registers were no longer maintained are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	492	145	0.63
DOD Participants	110	0*	1

*Minimum detectable gamma exposure with NTS film dosimeter is 30 mR per film packet worn.

LIST OF REFERENCES

References are not indicated within the text of this report, but are included in this list by chapter or part. Most references are available for review at or through the DOE/NV Coordination and Information Center (CIC). Security-classified references are located at the DNA/HQ Technical Library in Alexandria, Virginia, but are available only to persons with appropriate security clearances and a need for classified information contained in the references.

The CIC is operated by REECo, the custodian of nuclear testing dosimetry and other radiological safety records for DOE/NV, and the custodian for DNA of reference documents for reports on DOD participation in atmospheric, oceanic, and underground nuclear weapons testing events and series. Arrangements may be made to review available references for this report at the CIC by contacting one of the following:

Health Physics Division
U.S. Department of Energy
Nevada Operations Office
2753 South Highland Avenue
Post Office Box 14100
Las Vegas, NV 89114

Commercial: (702) 295-0994
FTS: 575-0994

or

Manager, Coordination and Information Center
Reynolds Electrical & Engineering Co., Inc.
Post Office Box 14400
Las Vegas, NV 89114

Commercial: (702) 295-0748
FTS: 575-0748

Major source documents also are available through the National Technical Information Service (NTIS) and may be purchased from NTIS at the address and telephone number listed below:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Commercial: (703) 487-4650
(Sales Office)

References available through public bookstores and libraries, through the U.S. Government Printing Office, and only at the CIC are listed without asterisks. Asterisks after references or groups of references indicate availability as follows:

* Available through the NTIS and also located at the CIC.

** Located in the REECo Technical Information Office adjacent to the CIC, available through the CIC, and may be subject to Privacy Act restrictions.

*** Located in the DNA/HQ Technical Library, and subject to security clearance requirements.

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12. Atomic Energy Commission, Nevada Operations Office, NVOO Completion Report, Operation Grommet, 1 July 1971 through 30 June 1972, NVO-122, April 1973, Unpublished.

13. REECo Environmental Sciences Department field record archives are maintained chronologically and by test event and include the following:

    a. Procedures, Reentry Plans, Radsafe Plans, and Schedules of Events. **

    b. Correspondence. **

    c. Reports, including onsite Radsafe and offsite PHS event reports. **

    d. Exposure reports, Radsafe log books, Area Access Registers, radiation survey forms, telemetry forms, and other sampling and dosimetry forms. **

APPENDIX A

GLOSSARY OF TERMS

Activation Products	Nuclides made radioactive by neutrons from a nuclear detonation interacting with usually nonradioactive nuclides. Also called induced activity.
Advisory Panel	A group of experts formed to advise the Test Manager/Test Controller concerning operational factors affecting a test detonation.
AFSWC	The Air Force Special Weapons Center, located at Kirtland Air Force Base, Albuquerque, New Mexico. AFSWC provided air support to the AEC Test Manager for NTS testing activities.
AFSWP	The Armed Forces Special Weapons Project was activated on 1 January 1947, when the AEC was activated, to assume residual functions of the U.S. Army Manhattan Engineer District (see DASA).
Air Support	Aircraft, facilities, and personnel required for various support functions during testing, such as cloud sampling, cloud tracking, radiation monitoring, photography, and personnel and equipment transport.

Alpha Particle — A particle emitted spontaneously from the nucleus of the radionuclide, primarily heavy radionuclides. The particle is identical with the nucleus of a helium atom, having an atomic mass of four units and an electric charge of two positive units.

Anticontamination Clothing — Outer clothing worn to prevent contamination of personal clothing and the body, and the spread of contamination to uncontrolled areas.

Atmospheric Test Series — Each of several series of U.S. tests conducted from 1945 through 1962, when nuclear device detonations and experiments were conducted primarily in the atmosphere.

Attenuation — The process by which photons or particles from radioactive material are reduced in number or energy on passing through some medium.

Background Radiation — 1) Natural environmental radiation.

2) The radiations of man's natural environment, consisting of cosmic rays and those radiations which come from the naturally radioactive atoms of the earth, including those within man's body.

3) The term also may mean radiation extraneous to an experiment.

Ball Valve — Rotating spool valve designed to close off and provide a gas seal in an LOS pipe in less than one second. Can be pneumatic, hydraulic, or spring driven.

Beta Particle — A negatively charged particle of very small mass emitted from the nucleus of a radionuclide, particularly from the fission product radionuclides from nuclear detonations. Except for origin, the beta particle is identical with a high speed electron. Also may be a positively charged particle of the same very small mass called a positron.

BJY — The intersection of Mercury Highway with roads originally constructed for the BUSTER-JANGLE 1951 atmospheric test series, located at the NW corner of Area 3 on the NTS. Previously called the "Y."

Bulkhead — A wall or embankment constructed in a mine or tunnel to protect against earth slides, fire, water, or gas.

Button up Activities — A procedure which consists primarily of completing the stemming, accomplishing the electrical checklist of tunnel portal and trailer park facilities, closing the OBP, gas seal plug, and gas seal door inside the tunnel, clearing the controlled area, and preparing command post and monitoring stations for the actual nuclear detonation.

Cable Drift — A passageway tunnel, usually parallel to the LOS drift, also known as the access bypass or work drift, in which cables from various experiments in the LOS pipe were installed toward a cable alcove and then through a sealed shaft to the surface.

Cal-Seal — A commercial sealant that is high density, quick-drying, high strength, and resilient concrete.

Cassette — A holder or container for a sample, an experiment, or a group of experiments.

Ceiling Limit — There are certain substances for which use of a Threshold Limit Value is inappropriate. These are substances which are predominantly fast acting and whose threshole limit is more appropriately based on this response. The ceiling limit places a definite boundary which concentration should not be permitted to exceed.

Cellar — The larger diameter, first part of a drilled hole where valving and other equipment are located.

Chamber — A natural or man-made enclosed space or cavity.

Check Points or Check Stations — Geographic locations established and staffed to control entry into restricted areas.

Chimney — The volume of broken rock above an underground detonation cavity that falls downward when decreasing cavity gas pressure can no longer support the column of broken rock.

Chromatograph — A piece of equipment used to separate and analyze mixtures of chemical substances by chromatographic absorption.

Cloud Sampling — The process of collecting particulate and gaseous samples of an effluent cloud to determine the amount of airborne radioactivity, and/or for subsequent analysis of detonation characteristics. Sampling usually was accomplished by specially equipped aircraft.

Cloud Tracking — The process of monitoring and determining the drift and movement of an effluent cloud, either by radar or by radiation monitoring and visual sighting from aircraft.

Collar — See "Shaft Collar"

Console — A cabinet or panel containing instrumentation for monitoring or controlling electronic or mechanical devices.

Containment — The act of preventing any release of radioactive material into the environment. Used in reference to the stemming plug area, or at the TAPS, OBP, or gas seal plug. An event is said to have "contained" if no radioactive material is released beyond the stemmed portion of the tunnel.

Containment Assessment Drift — Another name for reentry drift.

Contamination —

1) Radioactive material in an undesirable location, usually fission and activation products of a nuclear detonation, or fissionable material from a device, incorporated with particles of dust or device debris.

2) The process of depositing radioactive material on, or spreading it to, an undesirable location, such as personnel, structures, equipment, and other surfaces outside a controlled area.

Crater — The depression formed on the earth's surface by a near-surface, surface, or underground detonation. Crater formation can occur by the scouring effect of airblast, by throw-out of broken surface material, or by surface subsidence resulting from underground cavity formation and subsequent rock fall, or chimneying to the surface.

Crater Experiment	A test designed to breach and excavate the ground surface, thereby forming an ejecta crater; as opposed to a sink or subsidence crater.
Dance Hall	A large alcove used for data recording equipment.
DASA	After 1959, AFSWP became the Defense Atomic Support Agency. See AFSWP.
D-Day	The term used to designate the day on which a test takes place.
D+1	The first day after a test event.
Decontamination	The reduction of amount or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; or (3) fixing and covering the contamination to attenuate the radiation emitted.
Device	Nuclear fission or fission and fusion materials together with the arming, fusing, firing, high explosive, canister, and diagnostic measurement equipment, that have not reached the development status of an operational weapon.

DNA	Defense Nuclear Agency. Successor to DASA.
DOD	The U.S. Department of Defense. The federal executive agency responsible for the defense of the United States. Includes the military services and special joint defense agencies.
Dose	A quantity (measured or accumulated) of ionizing (or nuclear) radiation energy absorbed by a medium, including a person.
Dose Rate	As a general rule, the amount of ionizing (or nuclear) radiation energy that an individual or material would absorb per unit of time. Dose rate is usually expressed as rads (or rems) per hour or multiples or divisions of these units.
Dosimeter	An instrument or device used to indicate the total accumulated dose of (or exposure to) ionizing radiation. Instruments or devices worn or carried by individuals are called personnel dosimeters.
dpm	Disintegrations per minute; a measure of radioactivity. Literally, atoms disintegrating per minute.
Draeger Multi-Gas Detector	An instrument used to detect toxic gases, such that a sample of the ambient

atmosphere is drawn through a selected chemical reagent tube which indicates the concentration of a toxic gas.

Dressed-Out	Dressed in anticontamination clothing and associated equipment.
Drift	A horizontal passageway excavated underground with one access opening. It is used interchangeably with tunnel at the NTS.
Drillhole Designations	PS-1V: Post-Shot drill hole number 1 - vertical PS-1D: Post-Shot drill hole number 1 - directional PS-1A: Post-Shot drill hole number 1 - angle Each 'S' added after any of the above notations indicates a "sidetrack" or change of direction in the drillhole.
Dry Run	A simulation of the functions occurring in the minutes before, during, and after the event. All timing and firing signals are sent in the proper sequence from the Control Room at CP-1. Each run begins with the first required timing and firing signal (normally minus 15 minutes) and ends with the firing signal. The audio countdown is transmitted over Net 1 (DNA) and on other

nets as agreed upon with appropriate agencies. There are various types of dry runs depending on the degree of participation required of the agencies involved.

Effects Experiments	Experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. Includes measurements of the changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Exoatmospheric	Outside the gaseous mass which envelopes the earth.
Explosimeter	A battery-operated detector calibrated to indicate the concentration in the ambient atmosphere of explosive gases and vapors as percent of the lower explosive limit (LEL) of methane gas.
Exposure	A measure expressed in roentgens (R) of the ionization produced by gamma rays (or x-rays) in air [or divisions of R; 1/1000 R = 1 milliroentgen (mR)]. The exposure rate is the exposure per unit of time, usually per hour but sometimes smaller or larger units (e.g., R/min, mR/h, R/day).

Film Badge	Used for the indirect measurement of exposure to ionizing radiation. Generally contains 2 or 3 films of differing sensitivity. Films are wrapped in paper (or other thin material) that blocks light but is readily penetrated by radiations or secondary charged particles resulting from radiations to be measured. The films are developed and the degree of darkening (or density) measured indicates the radiation exposure. Film dosimeters commonly are used to indicate gamma and x-ray exposures, and also can be designed to determine beta and neutron doses.
Fission	The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with an accompanying release of energy. The most important fissionable, or fissile, materials are uranium-235 and plutonium-239. Fission is caused by the absorption of a neutron.
Fission Products	A general term used for the complex mixture of radioactive nuclides (see Radionuclides) produced as a result of nuclear fission.
Fissionable Material	A synonym for fissile material, also extended to include material that can be fissioned by fast neutrons only, such as uranium-238. Used in reactor operations to mean reactor fuel.

Forward Control Point	A geographic location in the forward test area, usually adjacent to the closed (or secured) test area.
Full Power Full Frequency Dry Run	Similar in intent to Mandatory Full Participation dry run. The FPFF is sometimes combined with the Hot Dry Run (HDR). This run is optional with the device engineer. When conducted, the pipe will be under vacuum, telephones and intercoms disconnected, and tunnel utility and instrumentation power operated in event-day configuration. All instrumentation will be hooked up and operated in event-day configuration. Simulators will not be used.
Fusion	The combination of two very light nuclei (of atoms) to form a relatively heavier nucleus, with an accompanying release of energy. Also called thermonuclear fusion.
Gamma Rays	Electromagnetic radiations of high energy emitted from the nuclei of radionuclides, or bundles of energy called photons, which usually accompany other nuclear reactions, such as fission, neutron capture, and beta particle emission. Gamma rays, or photons, are identical with x-rays of the same energy, except that x-rays result from orbital electron reactions and are not produced in the nucleus.

Gamma Shine	Measurable gamma radiation intensity from an approaching radioactive cloud or passing cloud, as opposed to measurements from or in gamma emitting fallout. Also gamma radiation scattered by air molecules, as opposed to direct radiation from a gamma source.

Gamma Shine	Measurable gamma radiation intensity from an approaching radioactive cloud or passing cloud, as opposed to measurements from or in gamma emitting fallout. Also gamma radiation scattered by air molecules, as opposed to direct radiation from a gamma source.
Gas Seal Door	A steel door on the portal side of the gas seal plug. It is closed during button up with about a 10 psi gas pressure applied between the gas seal plug and the gas seal door as additional reassurance against low pressure leaks.
Gas Seal Plug	A containment feature within the tunnel complex; generally designed for 500° F and 500 psi. Sometimes called hasty plug. Similar to a lower level overburden plug, but is close to the portal and seals the entire tunnel complex.
Geiger-Mueller Counter	An instrument consisting of a Geiger tube and associated electronic equipment used to detect and measure (and sometimes record) nuclear radiation.
Geophone	An instrument used to detect vibrations in rock or soil. At NTS, used to detect remotely rock falls, earth movement, and cavity collapse underground giving audible signal and visual display data.

Ground Zero	The point in a test bed configuration where the device is located.
H-Hour	Time zero or exact time of detonation to the minute, second, or fraction of a second; as opposed to H + 1 which implies one hour after detonation, unless time units of seconds or minutes are listed.
Horizontal Line-of-Sight	General term used to refer to a family of events conducted in a horizontal tunnel. Sometimes used to refer to the pipe and vacuum system for such events.
Hot Line	A location on the edge of a radex area where exiting personnel remove anticontamination clothing and equipment and are monitored for contamination and decontaminated as necessary before release. Also used to denote the centerline of a fallout pattern.
Ion	An atomic particle or part of a molecule bearing an electric charge, usually a positively charged ion and a negatively charged ion are formed as a pair (e.g., A negatively charged electron displaced from its positively charged remaining atom).
Ionizing Radiation	Any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its passage through air or matter. Alpha and beta

particles produce all ion pairs directly, while the electrons of initial ion pairs produced by gamma rays and x-rays in turn produce secondary ionization in their paths.

Isotopes	Different types of atoms within the same element, all reacting approximately the same chemically, but differing in atomic weight and nuclear stability. For example, the element hydrogen has three isotopes; normal hydrogen is the most abundant, heavy hydrogen is called deuterium, and radioactive hydrogen is the radioisotope called tritium.
Keyed Concrete Plug	A concrete plug of greater diameter than the shaft or tunnel cross section, such that the concrete is poured into the surrounding rock, providing greater strength against overpressure from the nuclear detonation.
Leukemia Cluster	An apparent but unexpected or extraordinary group of leukemia cases within some number or group of persons.
Long Line	The longest sampling line into the tunnel which does not connect to the LOS pipe.
LOS Pipe	An evacuated pipe that extends from the device to the test chambers. The part of the vacuum system may be either horizontal or vertical, and it may connect

containment experiment protection and experiment hardware.

Mandating Full Participation Full Run — This is a dry run peculiar to DOD events. Its purpose is threefold: first, to check all experiments with the event site electrical system in its shot configuration; second, to check for crosstalk between experiments; and third, to operate all recording, timing, and monitoring equipment as close to shot configuration as is possible. The pipe will be under vacuum and the tunnel and portal instrumentation trailers will be cleared of personnel. After a successful MFP dry run, all interconnections necessary to place experiments into shot configuration from the MFP configuration will be made. Timing, firing, and monitoring system junction boxes will be locked and no changes will be made except with the express approval of device systems personnel and the Technical Director.

Manhattan Engineer District — The U.S. Army predecessor organization to the U.S. Atomic Energy Commission.

Manned Stations — Locations inside the closed and secured area which are occupied by authorized personnel during an event.

McCaa 2-Hour Breathing Apparatus — A self-contained respiratory device that supplies two hours of breathing oxygen.

mR — A radiation exposure term (see Exposure).

Mucking — Removal of loose rock from drilling and mining operations.

Noble Gases — Those inert gases which do not react with other elements at normal temperature and pressure (i.e., helium, neon, argon, krypton, xenon and sometimes radon).

Nuclear Device (vs. weapon or bomb) — A device in which most of the energy released in a detonation results from reactions of atomic nuclei, either fission, or fission and fusion. A device under development (see Device) is not considered a weapon or bomb. Both A- (or atomic) bombs and H- (or hydrogen) bombs could be called atomic weapons because both involve reactions of atomic nuclei. However, it has become customary to call weapons A-bombs if the energy comes from fission, and H-bombs if most of the energy comes from fusion (of the isotopes of hydrogen - see definition). A developmental nuclear device is not a weapon or weapon component until it can be mated to a delivery system.

Nuclear Device Tests	Tests carried out to supply information required for the design, improvement, or safety aspects of nuclear weapons, and to study the phenomena and effects associated with nuclear explosions.
Nuclear Weapon Tests	Tests to provide development and weapons effects information, which may or may not utilize a deliverable nuclear weapon.
Offsite	The detection of radioactivity offsite is defined as detected outside the Test Range Complex, an area that includes both the Nevada Test Site and the adjacent Nellis Air Force Range.
Onsite	A notation that radioactivity was detected onsite only is made for tests from which there was an unplanned release of radioactivity into the atmosphere that was not detectable beyond the boundaries of the Test Range Complex.
Overburden Plug	A containment feature within the tunnel complex. It is a high-strength concrete blockage of the tunnel near the test area and is generally designed for 1000° F and 1000 psi.
Party Monitors	Radiation monitors assigned to reentry and recovery parties or groups.

Privacy Act	The Privacy Act of 1974. Public Law 93-579. An Act to amend Title 5, U.S. Code, by adding Section 552a to safeguard individual privacy from the misuse of Federal Records, to provide that individuals be granted access to records concerning them which are maintained by federal agencies, to establish a Privacy Protection Study Commission, and for other purposes.
rad	Abbreviation for radiation absorbed dose. A unit of absorbed dose of radiation representing the absorption of 100 ergs of ionizing radiation per gram of absorbing material, including body tissue.
Radex Area	An acronym for radiation exclusion area. A radex area is any area which is controlled for the purpose of protecting individuals from exposure to radiation and/or radioactive material.
Radiation Exposure	Exposure to radiation may be described and modified by a number of terms. The type of radiation is important: external exposure is to beta particles, neutrons, gamma rays and X-rays; internal exposure is from radionuclides deposited within the body emitting alpha, beta, gamma or x-radiation and irradiating various body organs. (see Dose and Exposure).

Radioactive Effluent	The radioactive material, steam, smoke, dust, and other particulate debris released to the atmosphere from an underground nuclear detonation.
Radioactive or Fission Products	A general term for the complex mixture of radionuclides produced as a result of nuclear fission (see Activation Products).
Radionuclides	A collective term for all types of radioactive atoms of elements as opposed to stable nuclides (see Isotopes).
Recovery Operations	Process of finding and removing experiments, by-products, or data from the test area after a test event.
Red Shack	An underground (usually) intermediate point provided for the device laboratory's use in checking out and exercising the arming and firing system.
rem	A special unit of biological radiation dose equivalent; the name is derived from the initial letters of the term "roentgen equivalent man or mammal." The number of rem of radiation dose is equal to the number of rads multiplied by the quality factor (QF) and other factors of the given radiation.
roentgen	A special unit of exposure to gamma (or x-) radiation. It is defined precisely

as the quantity of gamma (or x-) rays that, when completely stopped, in air, will produce positive and negative ions with a total charge of 2.58×10^{-4} coulomb in one kilogram of dry air under standard conditions.

Safety Experiments — Device tests conducted to determine the safety of nuclear weapons during transportation and storage. Elements of the conventional high explosive portions of the devices were detonated to simulate accidental damage and to determine the potential for such simulated damage to result in significant nuclear yield. Data gained from the tests were used to develop devices that could withstand shock, blast, fire, and other accident conditions without producing a nuclear detonation.

Sandbag Plugs — Barriers used in tunnels, constructed of sandbags, to help contain underground detonations and minimize damage to underground workings.

Sandia Auxiliary Closure (SAC) — A device used to seal the HLOS pipe after the nuclear detonation.

Scientific Station — Distance in feet along the HLOS pipe measured from the zero point. These distances are generally expressed in whole numbers or to the nearest complete hundredths of feet if fractional.

Scientific Station 650 is expressed as SS650; Scientific Station 390.65 is expressed as SS390.65.

Scott-Draeger Self-contained Breathing Apparatus	Self-contained recirculating unit, complete with "full view" facepiece, compressed oxygen cylinder, breathing bag, carbon dioxide absorber, and pressure demand regulator is used when an extended exposure to an extremely hazardous or oxygen deficient atmosphere, or both, is required. This unit is capable of sustaining the wearer, under normal usage, for four to four and one-half hours; however, pertinent approved schedules limit NTS use to 2 hours.
Seismic Motion	Earth movement caused by an underground nuclear detonation, similar to a minor earthquake.
Shaft	A long narrow passage sunk into the earth. Shafts for device emplacement, ventilation, or access to underground workings may be drilled or mined.
Shaft Collar	The area immediately around the shaft at ground level, usually cemented, which supports the headframe and other equipment.
Shielding Walls	Walls or barriers used to protect equipment or instrumentation from heat, blast, and radioactivity.

Slushing Operations	The process of moving broken rock with a scraper or scraper bucket. May be used on the surface or underground, where ore or waste rock is slushed into hoppers or other locations for removal.
Spalling	Rock disintegration by flaking, chipping, peeling, or loosening of layers on the outside edges. May be caused immediately by rock stressing in proximity to a detonation point. Also results later, after continued stressing from temperature change expansion and contraction. Spalling also may result or begin when rock containing moisture is raised to a high temperature, and expanding vapor creates fractures. May also occur as a result of the rock.
Stemming	The materials used to back-fill or plug the emplacement shaft, drift, or LOS drift to contain overpressure and radioactive material from a nuclear detonation.
Surface Ground Zero	The location on the ground surface directly above an underground zero point or directly below an airburst.
Test Chamber	A section of the LOS pipe in which experiments are placed. It may or may not be enlarged, depending upon the test design.

Test Controller	A DOE official designated by the Manager, Nevada Operations Office, to assume responsibility for the field operations involved in conducting a nuclear test at the Nevada Test Site.
Test Event	The immediately preceeding preparations for, including arming and firing, and the testing of a nuclear device, including the detonation and concurrent measurements and effects.
Testing Organizations	Organizations conducting nuclear tests at the NTS (see DOD, DASA, LASL, LRL and SL).
Tonopah Test Range	Located in the northwest corner of Nellis Air Force Range near Tonopah, Nevada.
Trailer Park	Area near the portal or on the mesa where instrumentation or instrumentation support trailers are parked.
Tunnel	At NTS, a horizontal underground excavation driven on a predetermined line and grade to some specific target.
Tunnel Access	Entry to a tunnel or tunnel complex upon approval of the Test Director during test operations, or upon approval of the Tunnel Superintendent during routine operations.

Tunnel and Pipe Seal	(TAPS) An experiment protection feature along the LOS pipe which allows the experiments to be exposed to the desired levels of radiation while being protected from debris. It contains a massive steel door which closes after ground shock passes to form a 1000° F and 1000 psi seal.
Tunnel Complex	The complete set of drifts and support equipment comprising one tunnel.
Tunnel Walk-Out	A visual, walking inspection of the tunnel or tunnel complex, usually as a part of the initial reentry after a detonation, to check for hazards of any and all kinds prior to allowing general access to the underground workings.
Underground Structures Program	The construction and fabrication of test structures underground for the purpose of detonation effects evaluation.
User	An organization conducting tests at the NTS (See Testing Organizations).
Vela-Uniform	Department of Defense (DOD) program designed to improve the capability to detect, identify, and locate underground nuclear explosions.
Venting	Release of radioactive material, steam, smoke, dust and other particulate de-

bris through a zone of weakness from the detonation-formed cavity into the atmosphere.

Weapons Effects Experiments	Experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. Includes measurements of the changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Weather Briefings	A part of the Readiness Briefings which are meetings of test-associated administrators, advisors, and other technical personnel prior to each test event to evaluate weather conditions and forecasts on event day, and make decisions on any necessary operational schedule changes.
Workings	An excavation or group of excavations made in mining, quarrying, or tunneling, used chiefly in the plural, such as "the workings extended for miles underground."
x-rays	Electromagnetic radiations produced by electron reactions, as opposed to emission of gamma rays by nuclei. Otherwise high energy x-rays are identical with gamma rays of the same energy.

Yield — The total effective energy released by a nuclear detonation. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation (including residual radiation), thermal radiation, and blast and shock energy; the actual distribution depending on the medium in which the explosion occurs and also upon the type of weapon.

Zero Point — The location of a center of a burst of a nuclear weapon or device at the instant of detonation. The zero point may be above or below the surface of ground or water or otherwise offset.

APPENDIX B

ABBREVIATIONS AND ACRONYMS

The abbreviations and acronyms in the following list are used in the fourth volume of DOD underground testing reports. Additional information and definitions may be found in the text and in the Glossary of Terms.

AAVS	Aerospace Audio Visual Services
AEC	Atomic Energy Commission
AES	Auxiliary Experiment Station
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AFWL	Air Force Weapons Laboratory
AMC	Army Materiel Command
ASN	Air Surveillance Network
AVCO	AVCO Corporation
BAC	Boeing Aircraft Corporation
Bkg	Background Radiation Measurement
BJY	BUSTER-JANGLE roads intersection
BTL	Bell Telephone Laboratories
CC	Crosscut
CCTV	Closed Circuit Television
CDC	Centers for Disease Control
CEP	Containment Evaluation Panel
CETO	Civil Effects Test Organization
CIC	Coordination and Information Center
CP-1	Control Point Building 1
CP-2	Control Point Building 2
CTO	Continental Test Organization
D-Day	The day a nuclear detonation takes place
DASA	Defense Atomic Support Agency
DF	Distribution Factor
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
dpm	Disintegrations per minute
EG&G	EG&G, Inc. (formerly Edgerton, Germeshausen, & Grier)
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ES	Experiment Station
ETI	Effects Technology, Inc.
FCDASA	Field Command, Defense Atomic Support Agency
FCDNA	Field Command, Defense Nuclear Agency
FCP	Forward Control Point

F&S	Fenix & Scisson, Inc.
FPFF	Full Power Full Frequency
GA	General Atomic Corporation
GE	General Electric Corporation
GM	Geiger-Mueller
GZ	Ground Zero
HDL	Harry Diamond Laboratories
HE	High explosives (conventional)
H&N	Holmes & Narver, Inc.
ISAFAF	Indian Springs Air Force Auxiliary Field (formerly ISAFB)
ISAFB	Indian Springs Air Force Base
JCS	Joint Chiefs of Staff
KN	Kaman Nuclear
KSC	Kaman Sciences, Corp. (formerly Kaman Nuclear)
kt	Kilotons
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory (now Los Alamos National Laboratory)
LEL	Lower explosive limit
LLL	Lawrence Livermore Laboratory (formerly LRL)
LLNL	Lawrence Livermore National Laboratory
LMSC	Lockheed Missile and Space Corporation
LOS	Line-of-sight
LPARL	Lockheed Palo Alto Research Laboratory
LRL	Lawrence Radiation Laboratory (now Lawrence Livermore National Laboratory)
MDAC	McDonnell Douglas Aircraft Corp.
MFP	Mandatory Full Participation
MIT	Massachusetts Institute of Technology
MPC	Maximum permissible concentration
MRC	Moleculon Research Corporation
mrem/qt	Millirem per quarter
mrem/yr	Millirem per year
mR/h	Milliroentgens per hour
MSA	Mine Safety Appliance
MSL	Mean sea level
NATS	Nevada Aerial Tracking System
NDL	Army Chemical Corps Nuclear Defense Laboratory
NOL	Naval Ordnance Laboratory
NO_2	Nitrogen dioxide
$NO+NO_2$	Nitric oxide plus nitrogen dioxide
NPG	Nevada Proving Ground
NRDS	Nuclear Rocket Development Station
NRL	Naval Research Laboratory
NSC	National Security Council
NTS	Nevada Test Site
NTSO	Nevada Test Site Organization
NVOO	Nevada Operations Office
OBP	Overburden Plug
PDT	Pacific Daylight Time
PHS	United States Public Health Service (now Environmental Protection Agency

PI	Physics International
ppm	Parts per million
psi	Pounds per square inch
PST	Pacific Standard Time
QF	Quality Factor
Radex Area	Radiation Exclusion Area
rad/h	Radiation absorbed dose per hour
Radsafe	Radiological Sciences Department (formerly Radiological Safety Department), REECo
radsafe	Radiological Safety, in general
RAMS	Remote area monitoring system
RCG	Radioactivity concentration guide
REECo	Reynolds Electrical & Engineering Company, Incorporated
rem	Roentgen equivalent man or mammal
R/h	Roentgens per hour
RPG	Radiation protection guide
SAC	Sandia Auxiliary Closure
SAMSO	Space and Missile Systems Organization
SC	Sandia Corporation (now Sandia National Laboratories)
SGZ	Surface Ground Zero
SLA	Sandia Laboratories, Albuquerque (now Sandia National Laboratories)
SNL	Sandia National Laboratories
SOP	Standard operating procedures
SRI	Stanford Research Institute
SSS	Systems, Science and Software
TAPS	Tunnel and Pipe Seal
TC	Test Chamber
TCDASA	Test Command, Defense Atomic Support Agency
TEP	Test Evaluation Panel
TGD	Test Group Director
TGS	Test Group Staff
TNT	High explosive chemical (trinitrotoluene)
TTR	Tonopah Test Range
USAF	United States Air Force
USGS	U.S. Geological Survey
VA	Veterans Administration
VLOS	Vertical line-of-sight
WSI	Wackenhut Services, Incorporated

APPENDIX C

SC-M-68-227

GENERAL TUNNEL REENTRY PROCEDURES FOR DEPARTMENT OF DEFENSE AND SANDIA LABORATORY NUCLEAR TESTS

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April 1968

ABSTRACT

This document describes preshot preparations and postshot procedures for safe and economical reentry into a tunnel area after a nuclear detonation. Associated responsibilities, possible hazards, reentry ground rules, preshot preparations, communications, reentry parties and equipment, initial tunnel reentries, and recovery of scientific experiments are explained.

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L E G A L   N O T I C E

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GENERAL TUNNEL REENTRY PROCEDURES FOR
DEPARTMENT OF DEFENSE AND SANDIA LABORATORY NUCLEAR TESTS

1. Introduction

The Health Physics Division began tunnel reentries in 1962. The procedures that are given in this document represent a compilation of a series of tunnel reentry procedures that have been continually improved based upon experience and better instrumentation. The reentry plan presented describes preshot preparations and postshot procedures for safe and economical reentry and scientific recovery in a tunnel area.

2. Responsibilities

Responsibilities for safe and economical tunnel reentry procedures after a nuclear detonation indicated herein for AEC or AEC contractor (i.e., Sandia Laboratory) personnel are in accord with established AEC/DOD agreement or are the subject of separate action between TC/DASA and NVOO.

a. AEC-NVOO

(1) The Test Manager is responsible to the AEC for the safety of all the participating personnel at sites under the jurisdiction of NVOO and has approval authority over decisions effecting the safety of these personnel. (Ref: NTSO Draft 0524-013a.)

(2) The NVOO Operational Safety Division will advise the DOD Test Group Director (TGD) and the Reentry Control Group on all problems pertaining to health and safety.

b. Sandia Laboratory

(1) The Sandia Laboratory Health Physics Division has three responsibilities: It specifies the necessary measuring devices and equipment to indicate the postshot condition of the tunnel; it provides the Reentry Control Group; and it documents any release of radioactive material.

(2) The Chief of the Reentry Control Group will act as advisor to the TGD on surface and tunnel reentry safety until the tunnel has been cleared for normal operation.

(3) The Reentry Control Group will provide consultants who will advise on tunnel reentry procedures. These consultants will be familiar

with the experimental setup and with possible postshot tunnel conditions and hazards.

(4) The Reentry Control Group will arrange the necessary support for reentry and recovery, e.g., it will provide mine rescue trained personnel, Rad-Safe support (see Annex A), Industrial Hygiene Support, etc.

c. TC/DASA or Sandia Laboratory Test Group Director

(1) The TGD is responsible for the safe conduct of all activities in the tunnel area. He will authorize and initiate both a tunnel condition survey and reentry and recovery operations with the concurrence of the Test Manager.

(2) The TGD will be responsible for initiating all action for the preshot installation and postshot removal of equipment and services required for Test Group support activities except those items covered as AEC responsibilities in the AEC/DOD agreement.

3. Possible Hazards

a. Radiation. Radiation in tunnel reentry areas may result from any one of the following:

(1) Leak of radioactive gases or materials through fissures or fractures from ground zero.

(2) Failure of the tunnel stemming.

(3) Activation and/or dispersion of samples in the experimental chamber.

b. Explosive or toxic gases. Various explosive and toxic gases released as direct or secondary products of the detonation may be present in concentrations dangerous to personnel.

c. Explosives. Undetonated HE may remain either intact or scattered in the tunnel.

d. Toxic materials. Beryllium may pose a toxic problem to personnel particularly if it becomes dispersed in the air and/or deposited on recovery samples.

e. Tunnel damage. Damage to the tunnel may result from the device generated shock wave.

(1) Collapse of the tunnel would not normally be expected beyond the stemming; however, partial or total collapse may occur at greater distances from ground zero. Reentry through collapse zones must be preceded by mining through broken ground or by driving a new parallel drift.

(2) Heave of the tunnel floor may cause slabbing or spallation of the rock and failure of utility lines, railroad track, tunnel sets, and lagging. This damage will create safety hazards which must be removed prior to experimental recoveries.

f. High pressure gas. High pressure (2200 psi) gas cylinders normally exist within the tunnel complex.

4. Reentry Ground Rules

a. Initial reentry and each subsequent phase will be initiated upon authorization of the TGD with concurrence of the Test Manager, and control will be retained by the TGD until all recovery operations are completed and tunnel access is returned to AEC control. Only those personnel authorized by the TGD and the Chief of the Reentry Control Group will be permitted in the portal area and tunnel.

b. Tunnel communications will be by a hard wire portable phone system.

c. Tunnel parties will be controlled by the Chief of the Reentry Control Group who is located at the tunnel portal. Tunnel parties may be recalled at his direction. Only one team will be in the tunnel at any single time unless directed otherwise by the Chief of the Reentry Control Group.

d. A tunnel party will return to the portal under any of the following conditions:

(1) Upon decision of the Team Chief.

(2) When any member of Teams 1, 2, 3, and 4* show a McCaa oxygen supply less than 30 atmospheres or a Draeger pressure less than 450 psi.

(3) Upon loss of communications with the Reentry Control Group at the portal.

e. Team 4 (Rescue Team) will be dispatched upon direction of the Chief of the Reentry Control Group, the Team Chief in the tunnel, or if communications should be lost with any team in the tunnel (allowing a reasonable time for the team to exit after loss of communications).

f. All observations during reentry will be communicated through the Chief of Party to the Chief of the Reentry Control Group and recorded for future reference.

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*See Paragraph 7, "Reentry Parties and Equipment," for a description of the personnel, function, and equipment of each team.

g. Personnel radiation exposure limits are those set by NTS SOP Chapter 0524. The radiation dose limit for the operation is 3 Rem per calendar quarter. A person's exposure, however, will be terminated when his pocket dosimeter reaches 2.0 Rem, assuming his exposure history would allow 3 Rem during this operation.

h. Tunnel reentry will not be made before the tunnel ventilation has been turned on and samples of the air monitored at the portal. Evaluation of the sample must indicate that reentry can be made within the limitations of this procedure.

i. Reentry will not be made beyond ventilation, 10R/hr, 1000 ppm CO, or 10 percent of the lower explosive limit of explosive gas mixtures. Teams 1, 2, 3, and 4 may be exempted from these requirements under extenuating circumstances by mutual decision of the Chief of the Reentry Control Group and the Chief of the Party.

j. The Rescue Team will always be stationed near the portal with a train for immediate dispatch.

5. Summary of Preshot Preparations for Reentry

a. Stemming should provide fireball containment and should reduce radioactivity and explosive gas in the reentry area. The overburden plug should contain any debris that may pass the stemming. The gas seal door should contain any gases that penetrate the overburden plug.

b. Remote radiation sensing instruments will provide knowledge of tunnel radiation levels, while tunnel condition indicators (geophones, pressure and temperature gages, and explosimeters) remotely monitor the tunnel.

c. Air sampling lines for gas chromatography are normally installed through both the gas seal door and the overburden plug. Each installation is provided with suitable remotely operated valves. Samples may be drawn from the inside of the gas seal door, from both sides of the overburden plug, and from near the stemming. Sampling from these lines will help determine the explosive and toxic gas concentrations in the tunnel prior to reentry.

d. Valves are normally installed in the vent lines and makeup ports in the gas seal door and overburden plug. An axial vane fan is located on the makeup valves to reduce negative pressure. The valves and fan are remotely operated from a manned location and will have position monitors to indicate whether they are fully open or fully closed. The position monitors will also show whether the fan power is on or off.

e. The following items ordinarily have power turned on through and after zero time:

(1) Tunnel utilities and instrumentation. Power to these items will be turned off near zero time.

(2) Geophone transmitter trailer. This supplies power to the geophone and the pressure and temperature amplifiers which must be left on to monitor for cavity collapse and pressure changes.

(3) Ventilation fans. Power will be controlled remotely.

(4) Radiation detectors.

(5) Explosimeters.

(6) Ventilation and gas sampling valves. Power will be controlled remotely.

f. The Sutorbilt fans will be installed so they will pull air through the vent line filter system before it is released to the atmosphere. One Sutorbilt fan will be used for a back-up in case the other fan fails.

g. Ventilation.

(1) The ventilation system is installed so that all areas of the tunnel that are not closed off are swept with fresh air from the portal.

(2) After zero time and when the TGD gives his approval (with the consent of the Test Manager), the tunnel ventilation system will be turned on, exhaust and makeup air will be supplied from the portal through valves in the gas seal door and, if possible, the overburden plug. There will be valves that can be remotely operated in both vent lines at the gas seal door and, if possible, at the overburden plug. Vent line samples will be taken to monitor for radioactive, explosive, and/or toxic effluents.

6. <u>Communications</u>

A communication system with the necessary wire on a portable reel will be used during initial reentry. A back-up reel will be available. All conversation between the reentry party and reentry control will be recorded.

7. Reentry Parties and Equipment

The reentry parties will consist of the personnel and equipment described in the following table:

Party Name	Equipment
a. Teams 1, 2, and 3 - Tunnel Reentry Party (1) Chief of Party (2) Rad-Safe monitor (3) Industrial Hygiene monitor (May be performed by Rad-Science personnel) (4) Tunnel safety (5) Scientific Advisor (as required)	Full Radex clothing Bureau of Mines approved 2-hour self-contained oxygen breathing apparatus Radiation detectors Explosive gas meter Toxic gas detectors Oxygen percent meter Hard wire communications
b. Team 4 - Tunnel Rescue Party (1) Chief of Party (2) Three to six REE Co. Mine Rescue (3) Two monitors for Rad-Safe and Industrial Hygiene	Full Radex clothing Bureau of Mines approved 2-hour self-contained oxygen breathing apparatus Radiation detectors Toxic gas detectors Explosive gas meters Wire litters Hard wire communications
c. Team 5 - Tunnel Scientific Assessment Team (as required) (1) Chief of Party (2) Rad-Safe and Industrial Hygiene monitors (3) Scientific Advisors (4) Mine support	Full Radex clothing Respiratory protection (as required) Radiation detectors Toxic gas detectors Explosive gas meter Hard wire communications
d. Team 6 - Tunnel Work Party (1) Chief of Party (2) Rad-Safe and Industrial Hygiene monitors (3) REE Co. Miners	Full Radex clothing Respiratory protection (as required) Radiation detectors Toxic gas detectors
e. Team 7 - Tunnel Scientific Recoveries to Experimental Chamber (see Para. 9 for details)	Full Radex clothing Respiratory protection (as required)
f. Team 8 - HE Disposal Group (as required)	Full Radex clothing Respiratory protection (as required)
g. Team 9 - Medical Support M. D. and medical technician	Necessary medical equipment Ambulance

8. Initial Tunnel Reentries

a. After the event the TGD will review radiation and tunnel condition monitors. When he determines that it is safe, and with the agreement of the Test Manager, the tunnel ventilation system will be turned on EXHAUST. Makeup air will be supplied from the portal through the valves in the plugs.

b. Prior to entry into the tunnel, all experimental cables and all electrical and telephone lines going into the tunnel through the portal will be either locked open or disconnected. All other cables going into the tunnel will be disconnected and taped or cut and grouted as necessary. Along with the pressure, temperature, and geophone instruments, the remote radiation monitoring system and the remote explosimeters will be left connected. No circuit into the tunnel or into the instrumentation trailers will be closed when personnel are either in the tunnel or directly in front of the portal (including an area extending 50 feet on either side of the portal).

The Chief of the Reentry Control Group will advise the TGD on tunnel conditions by reviewing surface conditions, exhaust gas information, tunnel radiation, tunnel condition indicators, and seismic information. This review will determine when tunnel reentry may actually begin.

When cleared by the TGD and the Test Manager and when all surface recoveries and power checks are complete, Team 1 will be allowed to make the initial tunnel reentry. There will be no change in the tunnel ventilation setup or in utilities while Teams 1 through 5 are underground. The number of people in the portal area and trailer parks will be held to a minimum.

c. Team 1 will be the first group to reenter and will proceed to the gas seal door. A train may be used to supply transportation to the gas seal door, conditions permitting. Team 1 will continuously monitor for radioactivity and for toxic and explosive gases. Pressure gages at the gas seal door will be checked, and if no pressure is observed, a sample will be taken through the door to determine the environment on the other side of the door. Under safe conditions, Team 1 will then open the gas seal door. They will inspect the tunnel to the overburden plug. The pressure gages at the overburden plug will be checked and if no pressure is observed, a sample will be taken through the plug to determine the environment on the other side of the plug. Team 1 will then withdraw to the portal area. If remote ventilation has not been established previously behind the overburden plug, the work party (Team 6) will then reenter and take the necessary steps to establish ventilation through the plug. They will then exit the tunnel, and samples will be taken from the vent line to verify earlier remote sampling. A second work party may be required to open the overburden plug door and remove the material from the manway.

Team 2 will reenter with an engine and car containing the necessary equipment to open the overburden plug door. This group will take in the reel of communication wire and connect it up to the existing communication line jack at the overburden plug to reestablish communications with the reentry control group at the portal. Team 2 will open the manway door and will continuously monitor for radioactivity and for toxic and explosive gases. They will then withdraw to the portal with the engine.

Team 3 will reenter to the overburden plug and reestablish communications using the reel connected to the communication line jack. The team will walk out the remaining drift continuously monitoring for radioactivity and for toxic and explosive gases. They will also observe the vent lines to assure themselves that the lines are intact. Team 3 will proceed to the stemming, if possible, noting tunnel and pipe conditions. They will then return to the end of the experimental pipe and establish ventilation in the pipe if time and conditions permit. Swipes will be taken on the vent port of the test chamber and checked for contamination. These will be later analyzed for Be and isotope identification.

The mission of Teams 1, 2, and 3 is to verify that the tunnel complex is within acceptable levels for toxic and radioactive gases and to check the condition of the pipe and tunnel.

d. If Teams 1, 2, and 3 determine that tunnel rehabilitation may be safely conducted, they will leave the tunnel and Team 6 will make temporary repairs as needed to the vent line or tunnel. A Rad-Safe monitor will remain with Team 6 while in the tunnel and continue to monitor for radiation and toxic gases.

e. The object of Teams 1 and 3 will be to explore as much of the tunnel on one reentry as possible. Previous experience has shown that McCaa or Draeger Teams can explore up to 4300 feet in 1-1/2 hours with a 1/2 hour safety margin. If an additional initial reentry is required to fully explore the tunnel, Team 4 (with Rad-Safe and Industrial Hygiene monitors) will complete the tunnel exploration with Team 1 standing by as Tunnel Rescue.

9. Tunnel Scientific Recoveries from the Experimental Chamber

a. Scientific recoveries in the tunnel will not be permitted until Team 1, 2, or 3 has searched all drifts and verified that the tunnel is clear of dangerous amounts of toxic, explosive, and radioactive gases.

b. Before scientific recoveries may begin, repair of the tunnel along the recovery route to the experimental chamber must be complete. This activity may include repairing broken lagging and removing hazardous obstacles as well as repairing railroad track and vent lines. The tunnel lights will be turned on before all scientific recoveries except film recoveries begin. All cabling extending into a crushed zone will be cut.

c. Team 5 will conduct a technical survey and perform the necessary actions to begin scientific recoveries.

d. Team 7 will then be permitted to proceed to the experimental chamber and begin the removal of samples in order of priority. A Rad-Safe/ Industrial Safety monitor will be present at all times. This monitor will advise the Chief of the Reentry Control Group, who is responsible for terminating scientific recovery, whenever the tunnel environment becomes dangerous. A Rad-Safe check station will be established at each Scientific Station to control contamination.

APPENDIX D

U. S. ATOMIC ENERGY COMMISSION
STANDARD OPERATING PROCEDURE
NEVADA TEST SITE ORGANIZATION

NTSO-0524-01

Chapter 0524 RADIOLOGICAL SAFETY

0524-01 Radiological Safety

011 Purpose

The purpose of this Standard Operating Procedure is to define responsibility and to establish criteria and general procedures for radiological safety associated with NTS programs. Additional operational instructions relating to radiological safety for particular activities may be published as a part of the Test Manager's Operational Plan.

012 Responsibilities

a. Manager, NVOO. The Manager, NVOO, is the AEC official to whom the NTSO reports. The Manager, NVOO, as a Test Manager, is responsible for administering, preparing, and executing all programs and projects. The Test Manager may delegate operational control of the NTSO to specifically-identified Deputy Test Managers for the execution of approved programs, projects, and experiments. Only the Test Manager or the Deputy Test Manager is authorized to approve or disapprove the field execution of approved programs, projects or experiments.

b. Test Manager. The Test Manager is responsible for the protection of participating personnel and off-site population from radiation hazards associated with activities conducted at the NTS. By mutual agreement between the Test Manager and a scientific user, control of radiological safety within the area assigned for a particular activity may be delegated to the user's Test Group Director during the period of time when such control could have a direct bearing on the success or failure of the scientific program. The provisions of AEC Manual Chapter 8401 shall apply to reactor tests or sustained reactor operations.

c. Test Group Director. Whenever operational radiological safety control is delegated to a Test Group Director under provisions of 012a above, he is responsible to the Test Manager for establishment and implementation of radiological safety criteria within the assigned area. He will be responsible for submitting a detailed radiological safety operational plan to the

Revised: February 9, 1968

Test Manager for review and concurrence. This plan shall be submitted as Standard Operating Procedures (SOP) to cover all routine operations. Variances from the SOP for non-routine operations shall be presented to the Test Manager for review and concurrence. Upon termination of need for the Test Group Director to retain radiological safety control within an assigned area, the Test Group Director will be relieved of radiological safety responsibility.

d. Director, Nevada Test Site Support Office (NTSSO). Supervises the approved NTS on-site radiological safety programs, except for those periods in which operational control of specified areas may be delegated to others (i.e., Test Manager, Test Group Directors, etc.).

e. Radiological Safety Advisor. The NTSO Radiological Safety Advisor is responsible to the Test Manager for staff supervision of radiological safety policies and procedures at the NTS. Monitoring of the radiological safety policies and direction of procedures at NTS, during non-operational periods, rests with the Director, NTSSO.

f. Chief, Safety Branch (SB), NTSSO. The Chief, Safety Branch, NTSSO, will be responsible to the Director, NTSSO, for conducting field inspections at the NTS to assure that NTS contractors execute safety programs in accordance with approved safety procedures and plans as well as with AEC and NVOO directives. Recommends corrective actions where necessary. Assures that radioactive waste management and disposal are accomplished in accordance with approved procedures. Coordinates and administers NTS activities relative to the Radiological Assistance Program. Provides day-by-day coordination and monitoring of NTS radiological safety activities, except for those periods during which operational control of specified areas may be delegated to others.

g. Director, Safety Evaluation Division (SED), NVOO. Provides for staff development of safety programs of NVOO for use at NTS. Develops safety programs which are coordinated with NTSSO and site user agencies and organizations to meet public and operational safety requirements for the conduct of nuclear detonations, reactor test programs, chemical explosives tests, or other NVOO activities. Arranges for radiological studies as may be appropriate.

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h. Chief, Radiological Safety Branch (RSB), NVOO. Provides staff assistance in all matters relating to radiological safety. Reviews and evaluates for technical adequacy radiological safety procedures and operational plans submitted by user organizations. Acts as Radiological Safety Advisor (or provides a representative) to the Test Manager during all NVOO activities requiring such coverage.

i. Off-Site Radiological Safety Officer. The Director, Southwestern Radiological Health Laboratory, U. S. Public Health Service, or his representative, will be designated as the Off-Site Radiological Safety Officer and its responsible to the Test Manager for the operation of the off-site radiological safety program.

j. User Organizations. The official in charge of each agency or organizational group participating in NTS field activities or using NTS facilities is responsible for compliance by his personnel with established radiological safety policies, procedures and controls. Each official in charge of a participating group is also responsible at all times to his parent organization for the radiological safety of personnel under his supervision. Operational safety plans will be submitted by the user organization to the Test Manager for review and approval, with a copy to the Director, NTSSO.

k. Operations Coordination Center (OCC). Shipment of radioactive materials, radioactive waste disposal, and access to areas contaminated with radioactive debris require prior coordination through the Operations Coordination Center, CP-1, telephone Mercury 986-2781.

l. On-Site Radiological Organization. On-site radiological safety support services for user organizations and the routine operation of NTS will be provided by the on-site radiological safety support contractor as directed by the NTSSO. Routine radiological safety support services at NTS will be requested in writing by the user organization through the Director, NTSSO. The on-site radiological safety support contractor is responsible to the Test Manager, through the Director, NTSSO, for the following routine on-NTS radiological safety support.

1. Providing radiological safety support, including certified monitors to user organizations.

2. Making radiological surveys, documenting radiation levels from events on the NTS, mapping and properly marking all contaminated areas, and furnishing this survey information for distribution by the Chief, Safety Branch, NTSSO.

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3. Conducting a personnel radiation dosimetry program and disseminating the results of the program to respective organizations covered under this program, and as appropriate under AEC Manual Chapter 0525 and Appendix. This program to include providing and maintaining a repository for records and source documents pertaining to personnel dosimetry for all NVOO activities requiring such dosimetry.

4. Maintaining and calibrating radiation detection equipment.

5. Procuring, issuing, and decontaminating protective clothing, supplies, and equipment.

6. Providing radioactive materials and waste disposal control (including receiving, storage, on-site movement and shipping).

7. Maintaining and operating personnel and equipment decontamination facilities.

8. Providing advice and assistance in matters pertaining to radiological safety.

9. Conducting an on-site environmental surveillance program.

10. Providing necessary support services for the off-site radiological safety program.

11. Conducting radiological safety training courses.

12. Preparing final on-site reports following each test operational period, interim reports for each event, special reports and detailed operational plans for each future program.

13. Providing Radiological Assistance Teams to respond to radiation incidents.

14. Conducting analysis of samples for radioactivity and for certain toxic materials.

15. Providing and maintaining a current manual containing the Standard Operating Procedures (SOP) for providing radiological safety support, as outlined above, to users and contractors at the NTS.

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m. Other. Other responsibilities as well as more detailed versions of the above, are spelled out in NTSO-0103.

0524-02 Organization

The chart showing the organizational relationship of the NTS radiological safety activities is shown in Figure 1 on the following page.

0524-03 Definitions

a. Radiological Safety. The protection of personnel, population groups, and the environment from the effects of ionizing radiation.

b. Ionizing Radiation. Electromagnetic radiation (consisting of photons) or particulate radiation (consisting of electrons, neutrons, protons, etc.) usually of high energy, but in any case capable of ionizing air, directly or indirectly.

c. NTS. The Nevada Test Site.

d. On-Site. Areas within the NTS boundaries, including Mercury.

e. Certified Monitor. Any person certified to the Test Manager or his designated representative as a qualified monitor by a Test Group Director or the Radiological Safety Representative of the radiological safety services.

f. Radiation Exclusion Area (Radex). A limited access area designated and posted for radiological safety purposes.

g. Controlled Area. Any area to which access is controlled by the AEC or AEC contractors.

h. User. Any organization or test participant having a NVOO-approved technical program for conduct at the NTS.

i. Radiation Incident. Any alleged radiation accident, which if true, could result in property damage or loss, injury, over exposure, or excessive release of radioactive materials.

j. Roentgen. A unit of exposure to X or gamma radiation. 1 mR (one milliRoentgen) is one-one thousandth of one Roentgen.

k. Rad. A unit of absorbed dose equivalent to 100 ergs/gram.

Revised: February 9, 1968

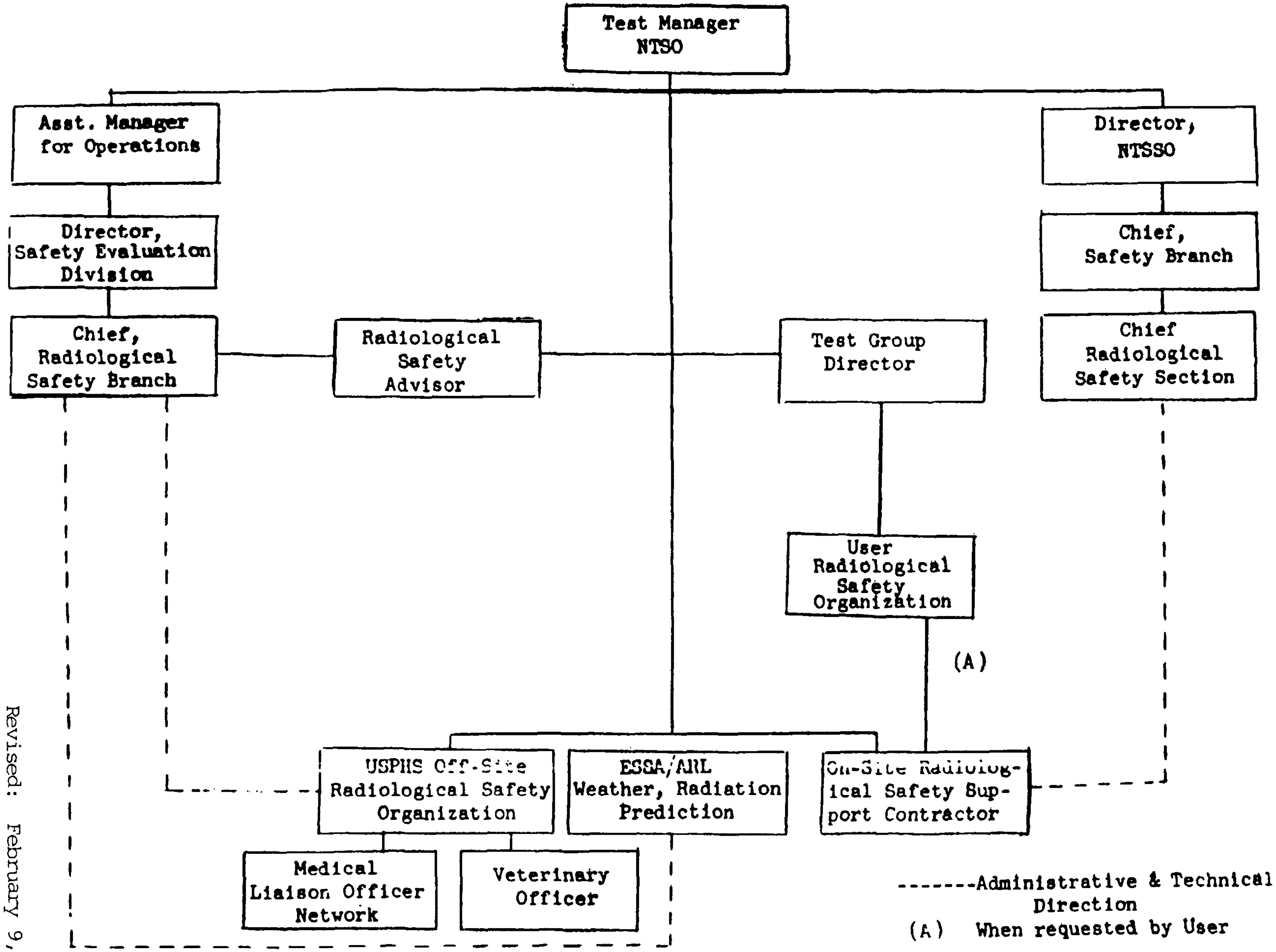

Figure I. Organization Chart
Radiological Safety Activities

l. Rem. A unit of dose equivalent. It is a unit found convenient in practice to express exposures to different types of ionizing radiation in terms that combine both the magnitude of the absorbed dose and its biological effectiveness. The dose equivalent is numerically equal to the dose in rads multiplied by the appropriate modifying factors.

m. Exposure Rate or Dose Rate. The time rate at which exposure or dose is measured or administered, i.e., dose or exposure per unit time, such as R/hr, rem/min, rad/hr, R/sec, etc.

0524-04 Radiation Protection Standards

041 Coverage. These standards shall govern ionizing radiation exposure to AEC and AEC contractor personnel and to other individuals who may be exposed to ionizing radiation from operations of the AEC and AEC contractors. These standards do not apply to radiation exposures resulting from natural radiation, medical and dental procedures, nor do they apply to the general population when the activities involved are essential to national security, such as nuclear weapons testing. The latter types of activities are covered by separate criteria. Safety criteria for each Plowshare event will be considered separately until such time as over-all policy for the Plowshare program is established. No operation shall be conducted until the radiological hazard has been evaluated and it has been determined to the satisfaction of the Test Manager, or the Test Group Director (when he has been delegated the radiological safety responsibility for the operation) that radiation exposures should not exceed the radiation protection standards established in AEC Manual Chapter 0524 (repeated below). Except for emergencies, written requests to expose personnel in excess of these limits should be directed to the Test Manager.

Revised: February 9, 1968

I. RADIATION PROTECTION STANDARDS FOR INDIVIDUALS IN CONTROLLED AREAS[1]

A. Radiation from sources external to the body

Type of Exposure	Period of Time	Dose (rem)
Whole body, head and trunk, active blood-forming organs gonads, or lens of eye.	Accumulated dose Calendar quarter[3]	5 (N-18)[2] 3[4]
Skin of whole body and thyroid	Year Calendar quarter[3]	30 10[4]
Hands, and forearms, feet and ankles	Year Calendar quarter[3]	75 25[4]

B. Radiation from emitters internal to the body

1. Except as provided in 2. below, the radiation protection standards for airborne radioactivity specified in annex I, table I, shall be followed. The concentration standards are based upon continuous exposure to the concentrations specified for forty hours per week (a "week" being seven consecutive days). For the purpose of applying these standards, radioactivity concentrations may be averaged over periods up to 13 consecutive weeks provided work areas are appropriately monitored and exposure histories are maintained for each individual working in such areas.

2. If it is not feasible to govern exposures to internal emitters by applying airborne radioactivity concentration standards, the following radiation protection standards shall apply:

Type of Exposure	Dose rem/year	 rem/quarter
Whole body, active blood-forming organs, gonads.	5	3
Thyroid	30	10
Bone	Body burden of 0.1 microgram of radium-226 or its biological equivalent[5]	--
Other organs	15	5

The calculation of organ dose shall be based on methods recommended by the Federal Radiation Council and the International Commission on Radiological Protection.

[1]An individual under age 18 shall not be employed in or allowed to enter controlled areas in such manner that he will receive doses of radiation in amounts exceeding the standards applicable to individuals in uncontrolled areas. Exposures to individuals under age 18 may be averaged over periods not to exceed one calendar quarter.

[2]N equals the age in years at last birthday. An individual employed at age 18 or an individual beyond age 18 who had no accrued unused exposure shall not be exposed during the ensuing year to doses exceeding (a) 1.25 rem for the first calendar quarter, (b) 2.5 rem total for the first two calendar quarters, (c) 3.75 rem total for the first three calendar quarters and (d) 5 rem for the year, but in no case will exposure be more than 3 rem per quarter.

[3]A calendar quarter may be taken as a predetermined period of 13 consecutive weeks or any predetermined quarter year based on the calendar.

[4]Personnel monitoring equipment shall be provided each individual who receives or is likely to receive a dose in any calendar quarter in excess of 10% of these values.

[5]Exposure must be governed such that the individual's body burden does not exceed this value (a) when averaged over any period of 12 consecutive months and (b) after 50 years of occupational exposure.

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II. RADIATION PROTECTION STANDARDS FOR INDIVIDUALS AND POPULATION GROUPS IN UNCONTROLLED AREAS

A. Radiation dose standards for external and internal exposure

	Dose (rem/year)	
Type of Exposure	Based on exposure to individuals	Based on an average exposure to a suitable population sample
Whole body, gonads or bone marrow	0.5	0.1
Thyroid or bone	1.5	0.5
Bone (alternate standard)	Body burden of 0.003μg of radium 226 or its biological equivalent.	Body burden of 0.001μg of radium 226 or its biological equivalent.

B. Radioactivity in effluents released to uncontrolled areas

1. Except as provided in 2. below, radioactivity in effluents released to uncontrolled areas shall not exceed the radiation protection standards specified in annex I, table II. The point of release of such effluents shall be considered to be the point at which the effluents pass beyond the site boundary. Where such effluents are discharged through a conduit such as a stack or pipe, the point of release may be considered to be the conduit discharge. For the purpose of applying these standards, radioactivity concentrations in effluents may be averaged over periods up to one year.

2. Radioactivity in effluents may be released to uncontrolled areas in excess of the radiation protection standards specified in annex I, table II, provided it is reasonably demonstrated that in uncontrolled areas:

   (a) individuals are not exposed in excess of the standards specified in A. above,

   (b) individuals are not exposed in excess of annex I, table II standards, or

   (c) the average exposure of a suitable sample of an exposed population group is not in excess of one-third of annex I, table II standards. Radioactivity concentrations in the environment may be averaged over periods up to one year.

3. In any situation in which the contribution to radioactivity in the environment from effluents discharged by one or more activities of the AEC or AEC contractors is likely to result in exposures in excess of the standards specified in II.A. and B. above, lower effluent concentration limits may be set for these Operations. In such cases, the manager of the field office may take the necessary corrective action if all activities concerned are within his area of responsibility. Otherwise, each case will be referred to the Director, Division of Operational Safety, for appropriate action.

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-5}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-8}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-8}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 244	S	4×10^{-6}	1×10^{-1}	1×10^{-7}	5×10^{-3}
		I	2×10^{-5}	1×10^{-1}	8×10^{-7}	5×10^{-3}
Antimony	Sb 122	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub[2]	6×10^{-3}	....	1×10^{-4}	....
	A 41	Sub	2×10^{-6}	....	4×10^{-8}	....
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-2}	1×10^{-8}	5×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-2}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-2}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-4}
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m ...	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	S	6×10^{-12}	2×10^{-4}	2×10^{-13}	7×10^{-6}
		I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
		I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C 14	S	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	(CO_2)	Sub	5×10^{-5}	....	1×10^{-6}	....
Cerium (58)	Ce 141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce 143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce 144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs 131	S	1×10^{-5}	7×10^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-2}	1×10^{-7}	9×10^{-4}
	Cs 134m ...	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs 134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	Cs 137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-8}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl 36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	2×10^{-8}	2×10^{-3}	8×10^{-10}	6×10^{-5}
	Cl 38	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr 51	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	2×10^{-6}	5×10^{-2}	8×10^{-8}	2×10^{-3}
Cobalt (27)	Co 57	S	3×10^{-6}	2×10^{-2}	1×10^{-7}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	6×10^{-9}	4×10^{-4}
	Co 58m	S	2×10^{-5}	8×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	6×10^{-2}	3×10^{-7}	2×10^{-3}
	Co 58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-8}	3×10^{-3}	2×10^{-9}	9×10^{-5}
	Co 60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	9×10^{-9}	1×10^{-3}	3×10^{-10}	3×10^{-5}
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
		I	2×10^{-10}	7×10^{-4}	6×10^{-12}	2×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-13}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m ...	S	5×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-5}

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2=9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-8}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2=13 yrs)	I	2×10^{-8}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	6×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge 71	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au 196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au 198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au 199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf 181	S	4×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
		I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H3	S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		Sub	2×10^{-3}	....	4×10^{-5}	
Indium (49)	In 113m ...	S	8×10^{-6}	4×10^{-2}	3×10^{-7}	1×10^{-3}
		I	7×10^{-6}	4×10^{-2}	2×10^{-7}	1×10^{-3}
	In 114m ...	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In 115m ...	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}

See footnotes at end of table.

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CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	In 115	S	$2x10^{-7}$	$3x10^{-3}$	$9x10^{-9}$	$9x10^{-5}$
		I	$3x10^{-8}$	$3x10^{-3}$	$1x10^{-9}$	$9x10^{-5}$
Iodine (53)	I 125	S	$5x10^{-9}$	$4x10^{-5}$	$8x10^{-11}$	$2x10^{-7}$
		I	$2x10^{-7}$	$6x10^{-3}$	$6x10^{-9}$	$2x10^{-4}$
	I 126	S	$8x10^{-9}$	$5x10^{-5}$	$9x10^{-11}$	$3x10^{-7}$
		I	$3x10^{-7}$	$3x10^{-3}$	$1x10^{-8}$	$9x10^{-5}$
	I 129	S	$2x10^{-9}$	$1x10^{-5}$	$2x10^{-11}$	$6x10^{-8}$
		I	$7x10^{-8}$	$6x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
	I 131	S	$9x10^{-9}$	$6x10^{-5}$	$1x10^{-10}$	$3x10^{-7}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	I 132	S	$2x10^{-7}$	$2x10^{-3}$	$3x10^{-9}$	$8x10^{-6}$
		I	$9x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	I 133	S	$3x10^{-8}$	$2x10^{-4}$	$4x10^{-10}$	$1x10^{-6}$
		I	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$4x10^{-5}$
	I 134	S	$5x10^{-7}$	$4x10^{-3}$	$6x10^{-9}$	$2x10^{-5}$
		I	$3x10^{-6}$	$2x10^{-2}$	$1x10^{-7}$	$6x10^{-4}$
	I 135	S	$1x10^{-7}$	$7x10^{-4}$	$1x10^{-9}$	$4x10^{-6}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
Irididum (77)	Ir 190	S	$1x10^{-6}$	$6x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
	Ir 192	S	$1x10^{-7}$	$1x10^{-3}$	$4x10^{-9}$	$4x10^{-5}$
		I	$3x10^{-8}$	$1x10^{-3}$	$9x10^{-10}$	$4x10^{-5}$
	Ir 194	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
Iron (26)	Fe 55	S	$9x10^{-7}$	$2x10^{-2}$	$3x10^{-8}$	$8x10^{-4}$
		I	$1x10^{-6}$	$7x10^{-2}$	$3x10^{-8}$	$2x10^{-3}$
	Fe 59	S	$1x10^{-7}$	$2x10^{-3}$	$5x10^{-9}$	$6x10^{-5}$
		I	$5x10^{-8}$	$2x10^{-3}$	$2x10^{-9}$	$5x10^{-5}$
Krypton (36)	Kr 85m	Sub	$6x10^{-6}$	....	$1x10^{-7}$	
	Kr 85	Sub	$1x10^{-5}$	....	$3x10^{-7}$	
	Kr 87	Sub	$1x10^{-6}$	....	$2x10^{-8}$	
	Kr 88	Sub	$1x10^{-6}$	....	$2x10^{-8}$	
Lanthanum (57)	La 140	S	$2x10^{-7}$	$7x10^{-4}$	$5x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$7x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
Lead (82)	Pb 203	S	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-6}$	$1x10^{-2}$	$6x10^{-8}$	$4x10^{-4}$
	Pb 210	S	$1x10^{-10}$	$4x10^{-6}$	$4x10^{-12}$	$1x10^{-7}$
		I	$2x10^{-10}$	$5x10^{-3}$	$8x10^{-12}$	$2x10^{-4}$
	Pb 212	S	$2x10^{-8}$	$6x10^{-4}$	$6x10^{-10}$	$2x10^{-5}$
		I	$2x10^{-8}$	$5x10^{-4}$	$7x10^{-10}$	$2x10^{-5}$
Lutetium (71)	Lu 177	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Manganese (25)	Mn 52	S	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$9x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
	Mn 54	S	$4x10^{-7}$	$4x10^{-3}$	$1x10^{-8}$	$1x10^{-4}$
		I	$4x10^{-8}$	$3x10^{-3}$	$1x10^{-9}$	$1x10^{-4}$

See footnotes at end of table.

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CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m ...	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
		I	8×10^{-7}	6×10^{-2}	3×10^{-8}	2×10^{-3}
	Ni 63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	7×10^{-4}
	Ni 65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41) ...	Nb 93m	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Nb 95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb 97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os 185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os 191m ...	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os 191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os 193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-2}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}

See footnotes at end of table.

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CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m ...	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Pt 193	S	1×10^{-6}	3×10^{-2}	4×10^{-8}	9×10^{-4}
		I	3×10^{-7}	5×10^{-2}	1×10^{-8}	2×10^{-3}
	Pt 197m ...	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-12}	1×10^{-4}	7×10^{-14}	5×10^{-6}
		I	3×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 239	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 240	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-12}	2×10^{-4}
		I	4×10^{-8}	4×10^{-2}	1×10^{-9}	1×10^{-3}
	Pu 242	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	9×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 243	S	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-2}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-5}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-4}	7×10^{-12}	3×10^{-5}
Potassium (19)	K42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-5}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-8}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-5}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-8}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-5}
Radon (86)	Rn 220	S	3×10^{-7}	....	1×10^{-8}	
	Rn 222[3]		3×10^{-8}	....	3×10^{-9}	
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-2}	9×10^{-8}	6×10^{-4}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-4}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Re 187	S	9×10^{-6}	7×10^{-2}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-2}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Rhodium (45)	Rh 103m ...	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-5}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-5}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-8}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-5}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-5}
	Sm 151	S	6×10^{-8}	1×10^{-2}	2×10^{-9}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	4×10^{-5}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium (34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m ...	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-8}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}
		I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr 90	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
		I	5×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Sr 91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr 92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S 35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
		I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}
Tantalum (73)	Ta 182	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	7×10^{-10}	4×10^{-5}
Technetium (43)	Tc 96m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-3}
		I	3×10^{-5}	3×10^{-1}	1×10^{-6}	1×10^{-2}
	Tc 96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Tc 97m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-4}
	Tc 97	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Tc 99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	1×10^{-5}	8×10^{-2}	5×10^{-7}	3×10^{-3}
	Tc 99	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Tellurium (52)	Te 125m ...	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
	Te 127m ...	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	4×10^{-8}	2×10^{-3}	1×10^{-9}	5×10^{-5}
	Te 127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Te 129m ...	S	8×10^{-8}	1×10^{-3}	3×10^{-9}	3×10^{-5}
		I	3×10^{-8}	6×10^{-4}	1×10^{-9}	2×10^{-5}

See footnotes at end of table.

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CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	Te 129	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	Te 131m ...	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
	Te 132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Terbium (65)	Tb 160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
Thallium (81)	Tl 200	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
	Tl 201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Tl 202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-5}
	Tl 204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	2×10^{-3}	9×10^{-10}	6×10^{-5}
Thorium (90)	Th 227	S	3×10^{-10}	5×10^{-4}	1×10^{-11}	2×10^{-5}
		I	2×10^{-10}	5×10^{-4}	6×10^{-12}	2×10^{-5}
	Th 228	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	6×10^{-12}	4×10^{-4}	2×10^{-13}	10^{-5}
	Th 230	S	2×10^{-12}	5×10^{-5}	8×10^{-14}	2×10^{-6}
		I	10^{-11}	9×10^{-4}	3×10^{-13}	3×10^{-5}
	Th 231	S	1×10^{-6}	7×10^{-3}	5×10^{-8}	2×10^{-4}
		I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
	Th 232	S	3×10^{-11}	5×10^{-5}	1×10^{-12}	2×10^{-6}
		I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-5}
	Th natural	S	6×10^{-11}	6×10^{-5}	2×10^{-12}	2×10^{-6}
		I	6×10^{-11}	6×10^{-4}	2×10^{-12}	2×10^{-5}
	Th 234	S	6×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	3×10^{-8}	5×10^{-4}	1×10^{-9}	2×10^{-5}
Thulium (69)	Tm 170	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		I	3×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
	Tm 171	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	8×10^{-9}	5×10^{-4}
Tin (50)	Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-5}
	Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Tungsten (Wolfram) (74)	W 181	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	4×10^{-9}	3×10^{-4}
	W 185	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
	W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Uranium (92)	U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
		I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}

See footnotes at end of table.

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CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	U 232	S	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
		I	3×10^{-11}	8×10^{-4}	9×10^{-13}	3×10^{-5}
	U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 234	S[4]	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 235	S[4]	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	U 238	S[4]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
	U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	U-natural .	S[4]	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
Vanadium (23)	V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
		I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)	Xe 131m ...	Sub	2×10^{-5}	....	4×10^{-7}	....
	Xe 133	Sub	1×10^{-5}	....	3×10^{-7}	....
	Xe 133m ...	Sub	1×10^{-5}	....	3×10^{-7}	....
	Xe 135	Sub	4×10^{-6}	....	1×10^{-7}	....
Ytterbium (70)	Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)	Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	Y 91m	S	2×10^{-5}	1×10^{-1}	8×10^{-7}	3×10^{-3}
		I	2×10^{-5}	1×10^{-1}	6×10^{-7}	3×10^{-3}
	Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-4}
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn 69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	8×10^{-4}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
	Zr 97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	9×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}

[1]Soluble (S); Insoluble (I).

[2]"Sub" means that values given are for submersion in an infinite cloud of gaseous material.

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Annex should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Annex I for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \frac{C_C}{MPC_C} \leq 1$$

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Annex I shall be:

a. For purposes of Table I, Col. 1-1 X 10^{-12}

b. For purposes of Table I, Col. 2-3 X 10^{-7}

c. For purposes of Table II, Col. 1-4 X 10^{-14}

d. For purposes of Table II, Col. 2-1 X 10^{-5}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the concentration limit for the mixture is the limit specified in Annex I for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Annex I are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Annex I for any radionuclide which is not known to be absent from the mixture; or

c. Element (atomic number) and isotope	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
If it is known that Sr 90, I 129, Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, and Th-nat, are not present.	....	$9x10^{-5}$	....	$3x10^{-6}$
If it is known that Sr 90, I 129, Pb 210, Po 210 Ra 223, Ra 226, Ra 228, Ra 231, and Th-nat, are not present.	....	$6x10^{-5}$	....	$2x10^{-6}$
If it is known that Sr 90, Pb 210, Ra 226, Ra 228, are not present.	....	$2x10^{-5}$	....	$6x10^{-7}$
If it is known Ra 226 and Ra 228, are not present.	....	$3x10^{-6}$	....	$1x10^{-7}$
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present.	$3x10^{-9}$	....	$1x10^{-10}$	....
If it is known that alpha-emitters and dPb 210, Ac 227, Ra 228 and Pu 241, are not present.	$3x10^{-10}$	....	$1x10^{-11}$	....
If it is known that alpha-emitters and Ac 227, are not present.	$3x10^{-11}$	....	$1x10^{-12}$	....
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, and Cf 249 are not present.	$3x10^{-12}$	....	$1x10^{-13}$	....
If Pa 231, Pu 239, Pu 240, Pu 242 and Cf 249 are not present.	$2x10^{-12}$	....	$7x10^{-14}$	....

4. If the mixture of radionuclides consists of uranium and its daughter products in ore dust prior to chemical processing of the uranium ore, the values specified below may be used in lieu of those determined in accordance with paragraph 1 above or those specified in paragraphs 2 and 3 above.

a. For purposes of Table I, Col. 1-$1x10^{-10}$ μc/ml gross alpha activity; or $2.5x10^{-11}$ μc/ml natural uranium; or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table I.I, Col. 1-$3x10^{-11}$ μc/ml gross alpha activity or $8x10^{-13}$ μc/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Annex I (MPC_A) does not exceed 1/10,

$$\text{i.e. } \frac{C_A}{MPC_A} \leq \frac{1}{10}$$

and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed 1/4.

$$\text{i.e. } \frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \ldots \leq \frac{1}{4}$$

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APPENDIX E

U.S. ATOMIC ENERGY COMMISSION
STANDARD OPERATING PROCEDURE
NEVADA TEST SITE ORGANIZATION

NTSO-0101-01

CHAPTER 0101 THE NEVADA TEST SITE ORGANIZATION (NTSO)

0101-01 General

011 The Nevada Test Site

The Nevada Test Site (NTS) is a facility provided by the Atomic Energy Commission and managed by the AEC Nevada Operations Office (NV). The NTS supports the field test programs of the AEC and its contractors, the Department of Defense, and others authorized to be conducted at the NTS.

012 The Nevada Test Site Organization (NTSO)

The Nevada Test Site Organization (NTSO) includes AEC, DOD, Laboratory, contractor, agency and organizational personnel who participate in, or provide support for, test operations at the Nevada Test Site (NTS). The Manager, NV, as the Site Manager, heads the NTSO (see Appendix "A").

0101-02 Organizational Concept and Policies

021 Nevada Test Site Organization (NTSO)

The Nevada Test Site Organization is a continuing task organization whose composition may be readily changed in response to the needs and technical objectives of the test program.

022 The NV staff, for the Manager, provides for the approval and coordination of program proposals, approvals for project support, funding and/or authority for financial agreement, legal counsel, contract authority and administration, engineering, accounting, classification and security policy and guidance, safety policy and guidance, environmental safety analyses, industrial relations, and public information policy to the NTSO.

023 Test execution shall conform to statutory, regulatory, and other responsibilities in accordance with delegations to the Manager, NV, by the General Manager of the Atomic Energy Commission.

024 Technical users are allowed maximum technical latitude in the conduct of their scientific programs and are responsible for their technical readiness.

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HT020

025 User groups may be assigned areas in which to conduct their operations and exercise technical control subject to operational site coordination and control exercised by the Site Manager or, during a Test Execution Period, the Test Controller.

026 The Site Manager, NTS, has the authority to approve or disapprove the field execution of tests that have been approved by Headquarters AEC. During the Test Execution Period, authority to proceed with or postpone the field execution of approved activities or tests is delegated to the Test Controller in accordance with his Delegation of Authority from the Manager, NV.

0101-03 Responsibilities

031 The Site Manager is responsible for administering the NTS, for all preparations required for the safe execution of programs and projects at the NTS and for providing construction and logistic support services and facilities required to support the technical users.

032 The Test Controller is responsible to the Manager, NV, for the conduct of those experiments and test events in the testing program to which he is assigned by the Manager, NV.

033 The Deputy, Military Matters (Director, Test Directorate, FCDNA), serves as deputy for the Site Manger on operational, administrative and support matters pertaining to all DNA activities.

034 The Scientific Manager's Advisory Panel is chaired by a Scientific Advisor designated by the Manager, NV, as nominated by the technical user. Members of the panel provide advice on matters relative to on- and off-site safety.

035 The Test Group Directors (TGD) are assigned by the scientific sponsor to direct the fielding and technical aspects of experiments and tests. He reports to the Test Controller on operational matters relating to test execution.

036 The Director, Logistics Support, is responsible for the direction and control of construction and logistical support activities at the NTS and during Test Execution Periods, supports the Test Controller directly in the field execution of experiments and test events.

037 The Director, Operational Support, aided by the Operations Control Group and Special Staff assigned from NV as required, provides advice, assistance and serves as principal operations coordinator for the Site Manager and during the Test Execution Period, as Director of Operations for the Test Controller.

038 The Control Point Coordinator assures the availability in the OCC of facilities and equipment for the control and coordination of NTS operational activities.

039 The Test Operations Officer supervises the preparation of the Test Controller's operation and security plan and other required plans as directed. He coordinates preparations for the test execution and forward area support. During the Test Execution Period, he assists the Director of Operations in supervising and coordinating execution of the operations and security plan as directed by the Test Controller.

040 The Test Liaison Officer provides oral communication of test-related operational information from the operational control point (NTS) to NV and the Test Operations Center (TOC), AEC HQ during the Test Execution Period.

041 The FCDNA, Test Construction Division, is responsible for directing DOD furnished support.

042 The Technical Program Groups consist of organizational units and staff to satisfy the program objectives of their parent organizations.

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1. PA CONTROL NUMBER: PA 13-385 — 1a. SUSPENSE:
2. PM / PHONE / EMAIL: Dr. Paul Blake, — 2a. DATE: 10 May 2013
3. BRANCH CHIEF / PHONE /EMAIL: N/A — 3a. DATE: N/A
4. DIVISION CHIEF / PHONE: N/A — 4a. DATE: N/A
5. DEPARTMENTS / PHONE: N/A — 5a. DATE: N/A
6. JDir/ OFFICE / PHONE: Byron L. Ristvet, DTRA Dep STI Mgr — 6a. DATE: 06 June 2013
7. PUBLIC AFFAIRS: Richard M. Ule — 7a. DATE: 10 Jun 2013

8. TITLE: DNA 6322F; DNA 6323F; DNA 6324F; DNA 6325F: DNA 6327F — 9. CONTRACT NUMBER:

10. ORIGINATOR: DNA

11. TYPE OF MATERIAL: [X] PAPER [ ] PRESENTATION [ ] ABSTRACT [ ] OTHER

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REMARKS CONT:
The following DNA Reports have been carefully reviewed and are recommended for public release. These reports are a part of the DoD/ DTRA Nuclear Test Personnel Records program. In 1979, Admiral Robert Monroe, DNA Director directed that any DNA, DASA, or AFSWP reports supporting the NTPR program were to be reviewed, extracted, sanitized, etc., in order to provide them the public, such that appearance that the Agency was hiding relevant data could be adverted. The documents listed below are personnel-oriented histories of DoD participation in underground nuclear weapons testing during specific AEC, ERDA or DoE operations. Why these documents, which were originally assigned Distribution C, Critical Technology, but not included in that review direction is unknown. However, I, as UGT SME, and Herb Hoppe have reviewed and in our judgement see no reason for restricted distribution. We recommend their immediate public release. The five reports are:

DNA 6322F, Operations CROSSTIE and BOWLINE, 31 August 1967 - 20 November 1968.
DNA 6323F, Operations MANDREL and GROMMET, 12 September 1969 to 02 May 1972
DNA 6324F, Operations TOGGLE, ARBOR, and BEDROCK, 20 July 1972 - 05 April 1975
DNA 6325F, Operations ANVIL, CRESSET, TINDERBOX, and GUARDIAN, 24 October 1975 - 31 October 1980
DNA6227F, Operations PRAETROIAN, PHALANX, FUSILLEER, AND GRENADIER, 23 September 19882 - 06 April 1985
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