Box 252

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DNA 6322F

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OPERATIONS CROSSTIE AND BOWLINE EVENTS

DOOR MIST, DORSAL FIN, MILK SHAKE, DIANA MOON, HUDSON SEAL, AND MING VASE

31 AUGUST 1967 - 20 NOVEMBER 1968

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United States Underground Nuclear Weapons Tests
Underground Nuclear Test Personnel Review

Prepared by Field Command, Defense Nuclear Agency

DNA 6322

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*
This report is a personnel-oriented history of DOD participation in underground nuclear weapons testing during OPERATIONS CROSSTIE AND BOWLINE, test events DOOR MIST, DORSAL FIN, MILK SHAKE, DIANA MOON, HUDSON SEAL, and MING VASE from 31 August 1967 through 20 November 1968. It is the third in a series of historical reports which will include all DOD underground nuclear weapons tests and all DOE underground nuclear weapons tests with significant DOD participation 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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Underground Test (UGT)	DORSAL FIN	MING VASE	
HUDSON SEAL	MILK SHAKE	CROSSTIE	

SUMMARY

Six Department of Defense (DOD)-sponsored underground test events were conducted from 31 August 1967 to 20 November 1968 to study weapons effects. Two were shaft-type and four were tunnel-type nuclear tests. The following table summarizes data on these events:

OPERATION	CROSSTIE			BOWLINE		
TEST EVENT	DOOR MIST	DORSAL FIN	MILK SHAKE	DIANA MOON	HUDSON SEAL	MING VASE
DATE	31 AUG 67	29 FEB 68	25 MAR 66	27 AUG 68	24 SEP 68	20 NOV 68
LOCAL TIME (hour)	0930 PDT	0908 PST	1044 PST	0930 PDT	1005 PDT	1000 PST
NTS LOCATION	AREA 12	AREA 12	AREA 5	AREA 11	AREA 12	AREA 16
TYPE	TUNNEL	TUNNEL	SHAFT	SHAFT	TUNNEL	TUNNEL
DEPTH (feet)	1,463	1,345	867	794	1,130	1,010
YIELD	LOW	LOW	LOW	LOW	LOW	LOW

NOTE: LOW INDICATES LESS THAN 20 KILOTONS.

Releases of radioactive effluent to the atmosphere were detected both onsite and offsite after DOOR MIST, a tunnel-type event. Releases of radioactive effluent were detected only within the confines of the Nevada Test Site (NTS) after the MILK SHAKE and DIANA MOON events. No release of radioactive effluent was detected onsite or offsite after the DORSAL FIN, HUDSON SEAL, and MING VASE test events.

As recorded on Area Access Registers, 8,428 individual entries to radiation exclusion areas were made after the above DOD test events. Of this number 1,396 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 16 mR. The average gamma radiation exposure per entry for DOD-affiliated participants was 33 mR. The maximum exposure of a non-DOD participant during an entry was 1,625 mR. The maximum exposure of a DOD-affiliated participant was 1,185 mR. These exposures occurred on 29 November 1967 during reentry and recovery operations conducted after the DOOR MIST event.

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 Manhattan Engineer District 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 the Pacific and Nevada atmospheric test operations. The 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, the 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. That study has progressed to the point where a number of volumes describing DOD participation in atmospheric tests have been published by the Defense Nuclear Agency (DNA) as the executive agency for the DOD.

On 20 June 1979, the United States Senate Committee on Veterans' Affairs began hearings on Veterans' Claims for Dis-

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*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.

abilities 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 Department of Energy (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, the 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 third of several volumes regarding the participation and radiation exposures of DOD military and civilian participants in underground nuclear test events.

SERIES OF VOLUMES

Each volume of this series discusses DOD-sponsored underground test events, in chronological order, after presenting introductory and general information. The volumes cover all 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, except events conducted as nuclear test detection experiments where reentries and, subsequently, significant exposure of participants to radiation did not occur.

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

An additional volume will discuss 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 volumes will be a census of DOD personnel and their radiation exposure data. Distribution of these volumes will necessarily be 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, DNA, the Air Force Weapons Laboratory Technical Library, and Sandia National Laboratories 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 offsite 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. A 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 the 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 entitled 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 the 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.

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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 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 was a safety experiment on 22 February 1958 also conducted in Nevada. This experiment, the VENUS event, resulted in a yield less than one ton. These two tests were the beginning of a United States underground program that is currently the only method of testing permitted by treaty.

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 development tests in tunnels were conducted.

However, radioactive products from several of these tests were not completely contained underground. Containment of nuclear detonations was a new engineering challenge. Fully understanding and solving containment problems would require years of underground testing experience.

When the United States resumed testing on 15 September 1961, the initial 33 test events were underground including a single 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 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 development 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 were conducted in addition to weapons development 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 utilized device types designed to be equivalent to weapons, or in some instances actually to be used in weapons, to determine the effects of weapon detonations on structures, materials, and equipment. The devices generally were provided by one of the weapons development laboratories. However, the DOD sponsored weapons effects tests, and such tests usually involved greater numbers of participants and were more complex than the other categories of tests previously mentioned.

Effects of shock waves on rock formations, buildings, other structures, materials, and equipment have been tested. Effects of other detonation characteristics such as heat and radiation have been studied in the same manner. The most complex weapons effects tests have been those simulating high altitude detonations by using very large evacuated pipes hundreds of feet in length and containing experiments.

1.3 TEST EVENTS IN THIS VOLUME

Weapons effects tests conducted from 31 August 1967 to 20 November 1968 during Operation CROSSTIE and Operation BOWLINE are discussed in this volume. The objective of each of these tests was to determine the effects of a nuclear detonation environment on equipment and materials. Test events and execution dates are listed below.

1. DOOR MIST, 31 August 1967.
2. DORSAL FIN, 29 February 1968.
3. MILK SHAKE, 25 March 1968.
4. DIANA MOON, 27 August 1968.
5. HUDSON SEAL, 24 September 1968.
6. MING VASE, 20 November 1968.

1.4 DOD TESTING ORGANIZATION AND RESPONSIBILITIES

Administering the underground nuclear testing program at NTS was a joint AEC-DOD responsibility. The parallel nature of the AEC-DOD organizational structure is shown in Figure 1.1.

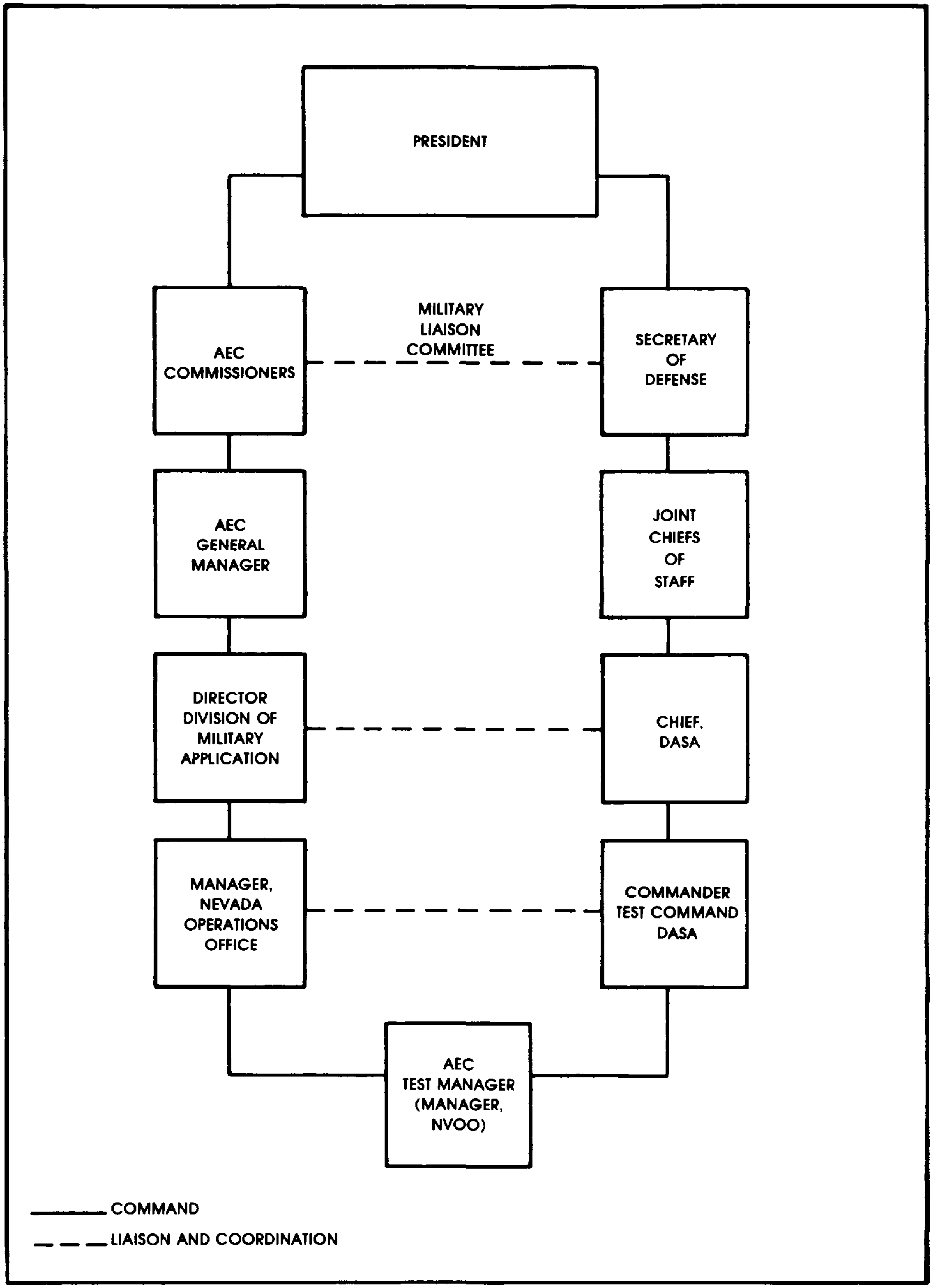

Figure 1.1 Federal Government structure for continental nuclear tests (during 1967-68).

1.4.1 Responsibilities of the Defense Atomic Support Agency

The Armed Forces Special Weapons Project (AFSWP) was activated on 1 January 1947 (when the Atomic Energy Commission was activated) to assume residual functions of the Manhattan Engineer District. The DOD nuclear weapons testing organization was within AFSWP until 1959 when AFSWP became the Defense Atomic Support Agency (DASA)*. The responsibilities of Headquarters, DASA, in Washington DC, included providing consolidated management and direction for the DOD nuclear weapons effects and nuclear weapons testing program. The technical direction and coordination of DOD nuclear weapons testing activities was delegated to Test Command, DASA (TC/DASA) headquartered in Albuquerque, New Mexico.

The responsibilities of TC/DASA in 1967 regarding DOD nuclear weapons testing activities were:

1. exercising technical direction of nuclear weapons effects tests of primary concern to the Armed Forces, and weapons effects phases of developmental or other tests of nuclear weapons involving detonations within the continental United States and overseas;

2. coordinating and supporting all DOD activities and assisting in support of the AEC in the conduct of joint tests involving nuclear detonations within the continental United States;

3. completing detailed plans, preparing for and conducting technical programs, and assisting in the preparation of technical and operational reports on tests; and

*DASA became the Defense Nuclear Agency (DNA) on 1 July 1971.

4. coordinating military operational training and DOD aspects of official visitor and public information programs. (Underground testing did not include troop participation and troop observers. The official visitor and public information programs were integrated with the AEC organization during joint AEC-DOD continental tests.)

These missions were accomplished for DOD underground nuclear tests through the Test Command Weapons Effects and Tests Group (TCWT). The TCWT testing organization included administrative operations at Kirtland AFB in Albuquerque, New Mexico, and operations at the Nevada Test Site.

1.4.2 Nevada Test Site Organization

In the joint AEC-DOD testing program, TCWT was a part of the Nevada Test Site Organization (NTSO) as shown in Figure 1.2. The Military Deputy to the Test Manager was the Deputy Chief of Staff, TCWT, and TCWT personnel provided DOD coordination and support.

The CTO was part of the original Nevada Test Site Organization along with the Los Alamos Scientific Laboratory (LASL), the Lawrence Radiation Laboratory (LRL), Sandia Corporation (SC), and the Civil Effects Test Organization (CETO). In addition to his position as Military Deputy to the Test Manager, the Deputy Chief of Staff, TCWT, was also the CTO Test Group Director. The CTO was disestablished on 1 August 1962 with its responsibilities being assumed by TCWT.

1.4.3 Air Force Special Weapons Center Support

The commander of the Air Force Special Weapons Center (AFSWC) was requested by TC/DASA to provide air support to the NTSO during nuclear tests at NTS. Direct support was provided by

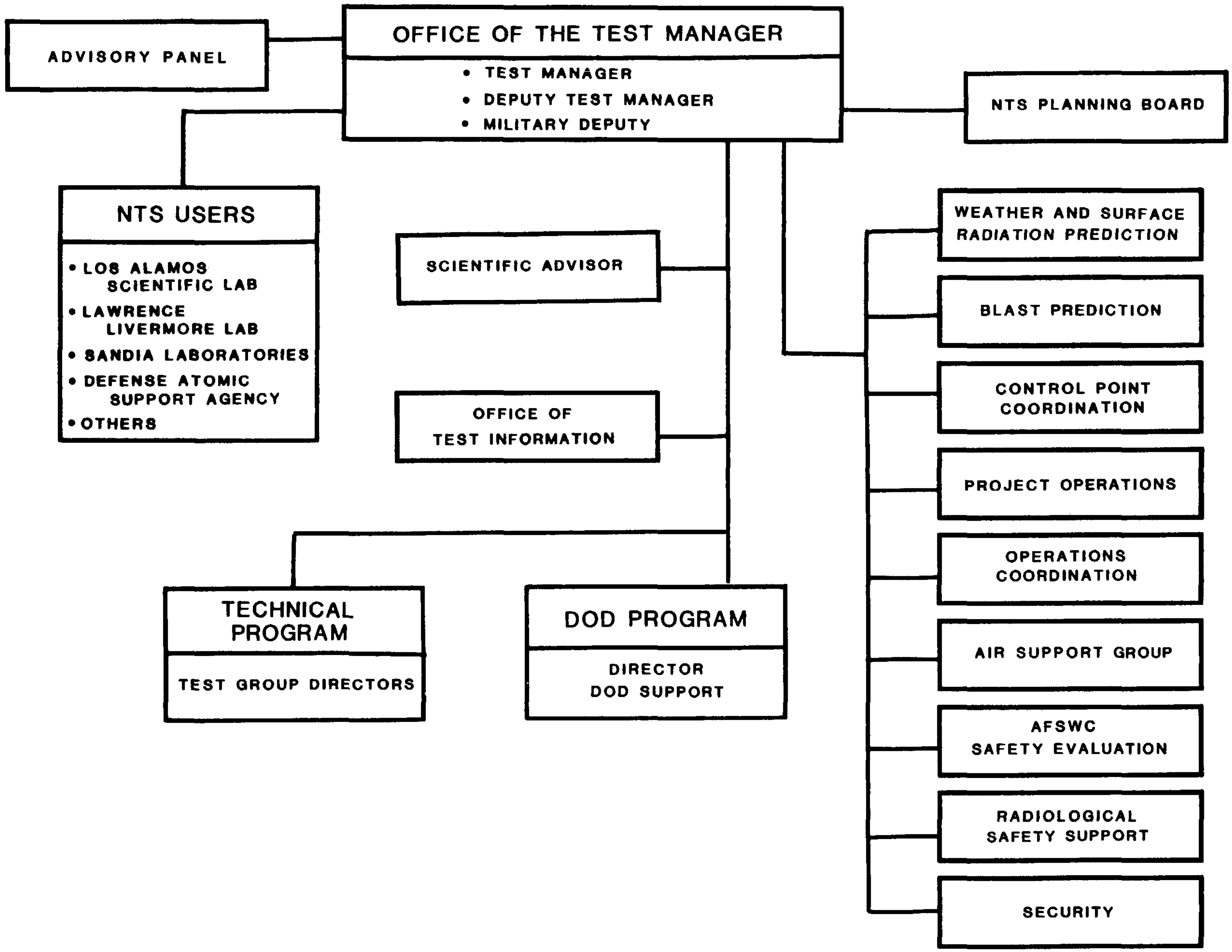

Figure 1.2 Nevada test site organization.

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 Kirtland AFB, New Mexico, and Indian Springs Air Force Auxiliary Field (ISAFAF) in Nevada. The 4900th also provided aircraft and crews to perform low-altitude cloud tracking and for radio relay 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 Air Transport Service, 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, food, 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 Air Transport Service, McClellan AFB, supplied one aircraft and a 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.

1.5 RELATIONSHIP OF THE DOD, THE AEC, AND CONTRACTOR ORGANIZATIONS

The DOD was responsible for establishing nuclear weapons criteria, developing and producing delivery vehicles, obtaining military effects data, and providing defense against nuclear attack.

The AEC was responsible for development, production, and supply of nuclear weapons to the Armed Forces in quantities and types specified by the Joint Chiefs of Staff (JCS). The AEC, in association with the DOD, also was responsible for providing field nuclear test facilities in the continental United States and overseas.

1.5.1 Test Command/DASA (TC/DASA) and the Nevada Operations Office (AEC/NVOO)

The principal points of field coordination between the AEC and the DOD were at Las Vegas and the Nevada Test Site. From 1 August 1966 to 1 July 1971, TC/DASA represented the Director, DASA and DOD. The AEC/NVOO represented the AEC in the field for continental tests. Each organization's primary interest was field testing of nuclear weapons. Close liaison was maintained between TC/DASA and AEC/NVOO during planning phases for field test programs of primary interest to the DOD.

During test operations, military and AEC personnel were combined into a single test organization. Normally, the Manager, NVOO was the senior member of the combined test organization and the Director, Directorate of Nuclear Field Operations, TC/DASA, was his deputy. Other personnel in this joint test organization were selected from those available on a best-qualified basis. In accomplishing this, personnel were drawn not only from TC/DASA and NVOO but from other agencies of DASA, the Armed Forces, military laboratories, military contractors, universities, civilian laboratories, AEC laboratories, AEC contractors, other government agencies, and from other sources when special qualifications or knowledge were required.

Since the Nevada Test Site was an AEC installation, the Manager, NVOO, was responsible for its operation. The DOD and AEC laboratories were the principal users of the Test Site. The Directorate of Nuclear Field Operations, TC/DASA, was the point of contact for the Manager, NVOO, for all matters pertaining to DOD field test programs, and supported all DOD agencies operating at the Test Site.

To accomplish these two major responsibilities, TC/DASA had a Nevada Branch with a liaison office in the AEC building in Las Vegas and a larger office at Mercury, Nevada. The Nevada Branch maintained liaison with NVOO top management on all DOD matters pertaining to field operations, and supported DOD agencies at the Test Site by providing office and laboratory space, transportation, test equipment, logistical support, and administrative support as needed. All DOD personnel and DOD contractor personnel connected with field test were under administrative control of the Nevada Branch while in Las Vegas and at the Nevada Test Site.

1.5.2 Test Organizations

Before 1957, the Test Group Director for each series had been a LASL representative. For the 1957 PLUMBBOB series, an LRL staff member was appointed to the position, reflecting growing LRL participation in test operations. After 1961, the Test Group Director for events of primary interest to the DOD was generally an officer from one of the Services. The Test Group Director was responsible for overall coordination and scientific support for the entire scientific test program, including planning and coordination. Generally, the AEC weapons laboratories provided nuclear devices for DOD test events.

Other officials of the NTSO were responsible for various functions, such as logistical support, weather prediction, fall-out prediction, blast prediction, air support, public information, radiological safety, industrial safety, and fire protection.

LOS ALAMOS SCIENTIFIC LABORATORY was established early in 1943 as Los Alamos in New Mexico, 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 the Los Alamos Scientific Laboratory in January 1947 when the AEC and AFSWP were activated, and replaced the Manhattan Engineer District. 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 administered by the Commission's Albuquerque Operations Office. The Laboratory was operated by the University of California.

LAWRENCE RADIATION LABORATORY was established as a second AEC weapons laboratory at Livermore, California, in 1952. The Laboratory's responsibilities were essentially parallel to those of the Los Alamos Scientific Laboratory. Devices developed by LRL were first tested in Nevada in 1953, and they have been tested in each continental and Pacific series since. The contract under which LRL performed work for the AEC was administered by the Commission's San Francisco Operations Office. This Laboratory also was operated by the University of California.

SANDIA LABORATORY (later Sandia Laboratories) at Sandia Base, Albuquerque, New Mexico, was the AEC's other weapons laboratory. It was established in 1946 as a branch of the Los Alamos Scientific Laboratory, 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. Sandia

Laboratory'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 the Laboratory was established to provide closer support to developmental work of the LRL. Sandia Corporation also operated ballistic test facilities for the AEC at the Tonopah Ballistics Range (now Tonopah Test Range) near Tonopah, Nevada.

DEFENSE ATOMIC SUPPORT AGENCY was located in Washington, D.C. and was composed of personnel from the Armed Services and civilian DOD employees. It was activated on 1 January 1947 to assume certain residual functions of the Manhattan Engineer District and to assure continuity of technical military interest in nuclear weapons. The broad mission of DASA was planning specified technical services to the Army, Navy, Air Force, and Marine Corps in the military application of nuclear energy. Among the services performed were: 1) maintaining liaison with the AEC laboratories in the development of nuclear weapons, 2) planning and supervising the conduct of weapons effects tests and other field exercises, 3) providing nuclear weapons training to military personnel, and 4) storing and maintaining nuclear weapons. Early in the program for testing nuclear devices and weapons, DASA was given responsibility for planning and integrating with the AEC for military participation in full scale tests. After the NTS was activated, this planning responsibility was broadened to include conducting experimental programs of primary concern to the Armed Forces and coordinating other phases of military participation including assistance to the AEC. The Director, DASA, was responsible to the Joint Chiefs of Staff and the Secretary of Defense.

Test Command, DASA, located at Kirtland Air Force Base (then Sandia Base), New Mexico, carried out the weapon field testing responsibilities and seismic detection research responsibilities (VELA-UNIFORM) for the Director, DASA. This organization maintained close liaison with the AEC Nevada Operations Office. Personnel from the TC/DASA became the military members of the joint AEC-DOD test organization at the Nevada Test Site and other continental United States test locations. All participation of DOD agencies and their contractors in nuclear field tests was coordinated and supported by TC/DASA.

Nevada Branch at Mercury, Nevada, maintained liaison with AEC/NVOO and supervised TC/DASA activities at the Nevada Test Site. In addition to continental test responsibilities, TC/DASA provided key personnel for the military scientific test unit, and managed technical and scientific programs for DOD agencies and contractors during overseas tests.

1.5.3 Support Contractors

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

Reynolds Electrical & Engineering Company (REECo) 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 monitoring, communications and electronics, and occupational medicine. REECo maintained offices in Las Vegas and extensive facilities at the NTS.

Edgerton, Germeshausen & Grier, Inc., (EG&G) 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 facilities were maintained in Las Vegas and at the NTS.

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

Since 1963, Fenix & Scisson, Inc., (F&S) Tulsa, Oklahoma, was architect-engineer for drilling and mining operations in connection with underground nuclear testing. The company was involved in design and construction 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 the AEC and the DOD.

1.6 THE NEVADA TEST SITE

An on-continent location was selected for conducting nuclear weapons tests; construction began at the Nevada Proving Ground (NPG) in December 1950; and testing began in January 1951. This testing area was renamed the Nevada Test Site in 1955.

The original NPG boundaries were expanded as new projects and testing areas were added. Figure 1.3 shows the present NTS location bounded on three sides by the Nellis Air Force Range.

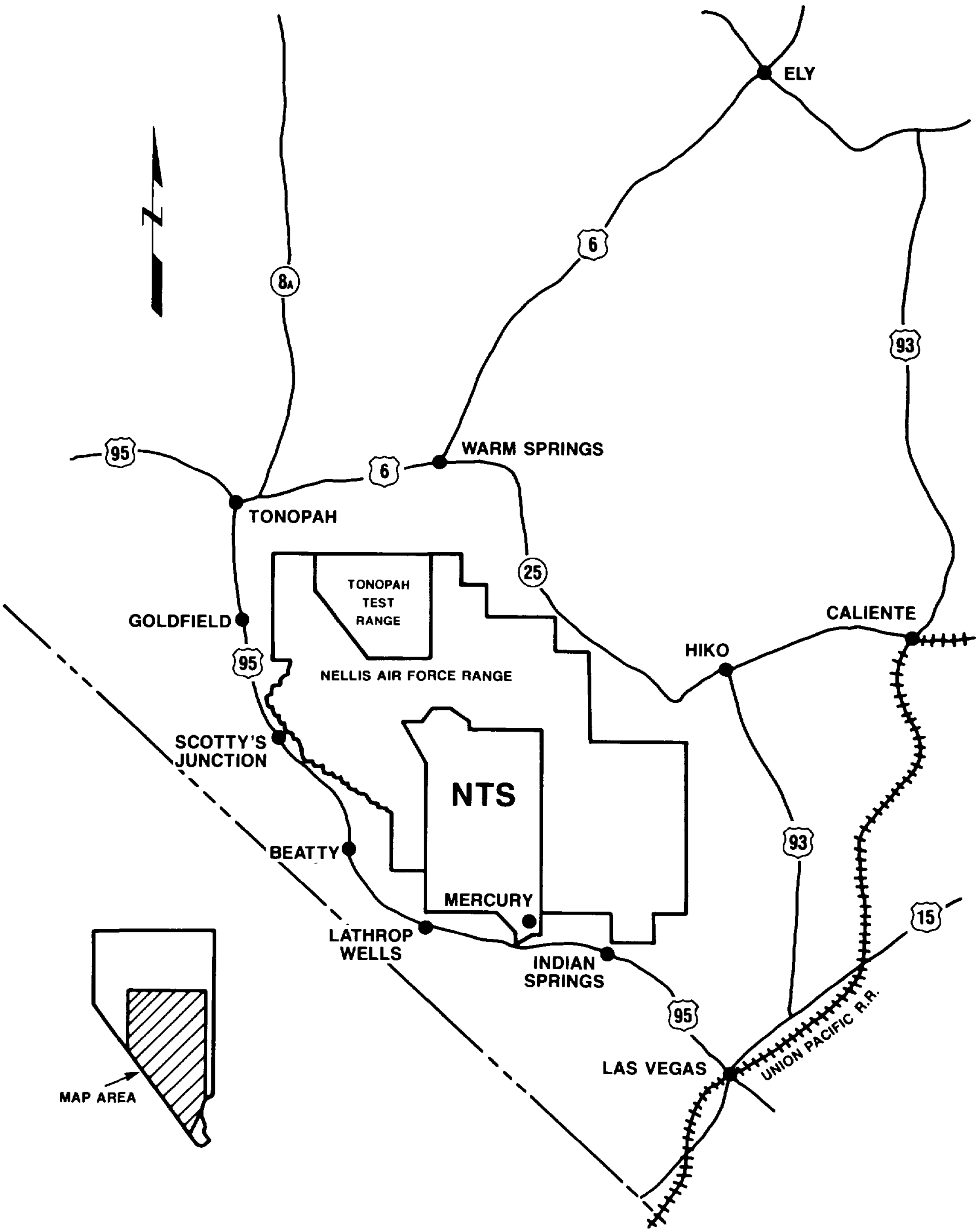

Figure 1.3 Nellis Air Force range and NTS in Nevada.

NTS encompasses about 1,350 square miles. 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 have combined to result in a very low population density in the area around the NTS.

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

Figure 1.4 shows the NTS, its various area designations, and the locations of the six test events covered by this volume. 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 "g.07" indicates the seventh drift from the main "g" tunnel, as U12g.07 in Figure 1.4.

A low mountain range separates the base camp, Mercury, from the location of early AEC amd DOD atmospheric weapons effects tests at Frenchman Flat in Area 5. A few shaft-type underground tests also were conducted in this area. 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.

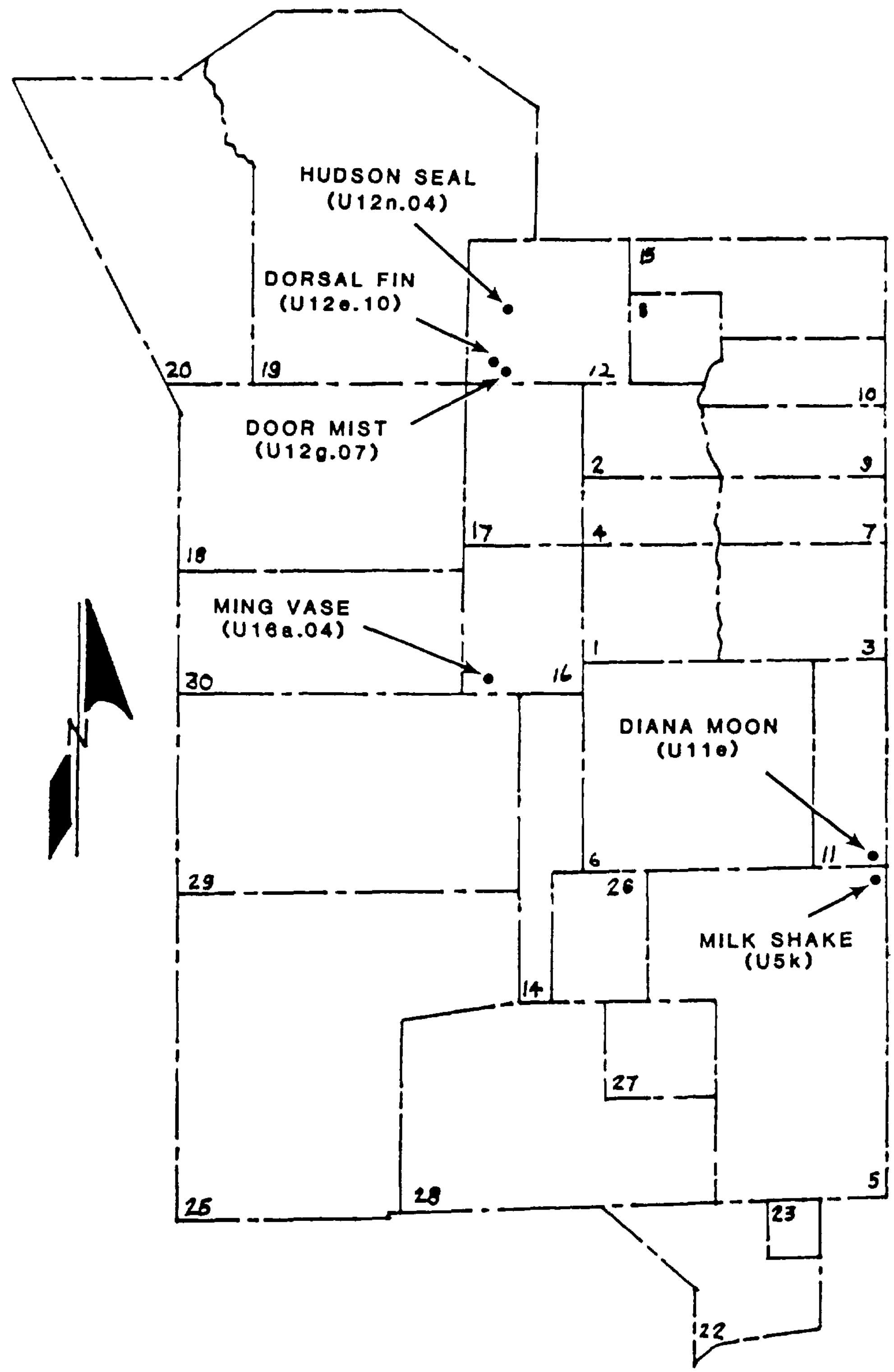

Figure 1.4 The Nevada test site.

Yucca Flat testing areas include Areas 1, 2, 3, 4, 7, 8, 9, and 10. Underground tests have been conducted in some 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. 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 the volume covering Operations NOUGAT and WHETSTONE while PILE DRIVER was discussed in the volume covering Operations FLINTLOCK and LATCHKEY.

CHAPTER 2

UNDERGROUND TESTING PROCEDURES

Underground tests conducted at NTS prior to 15 February 1962 primarily were for weapons related or safety experiment purposes. The experience gained contributed substantially to the DOD weapons effects testing program to be conducted underground. However, these later DOD underground tests generally were of greater complexity than previous underground tests, and a number of technical problems remained to be solved.

Obtaining satisfactory test data was an important objective, but equally important was the objective of assuring safety of test participants and the public. This chapter discusses historical underground testing methods, problems encountered, and safety procedures used during DOD underground weapons effects tests conducted from 31 August 1967 to 20 November 1968.

2.1 EMPLACEMENT TYPES

The DOD conducted six underground nuclear test events during this period. Table 2.1 lists these events and pertinent data including emplacement type. 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). There were two shaft and four tunnel type tests during Operations CROSSTIE and BOWLINE. These emplacement types are discussed in this section.

2.1.1 Shaft-Type

A shaft-type nuclear detonation was intended to be contained

Table 2.1. DOD test events, 31 August 1967 - 20 November 1968.

OPERATION	CROSSTIE			BOWLINE		
TEST EVENT	DOOR MIST	DORSAL FIN	MILK SHAKE	DIANA MOON	HUDSON SEAL	MING VASE
DATE	31 AUG 67	29 FEB 68	25 MAR 68	27 AUG 68	24 SEP 68	20 NOV 68
LOCAL TIME (hour)	0930 PDT	0908 PST	1044 PST	0930 PDT	1005 PDT	1000 PST
NTS LOCATION	AREA 12	AREA 12	AREA 5	AREA 11	AREA 12	AREA 16
TYPE	TUNNEL	TUNNEL	SHAFT	SHAFT	TUNNEL	TUNNEL
DEPTH (feet)	1,463	1,345	867	794	1,130	1,010
YIELD	LOW	LOW	LOW	LOW	LOW	LOW

NOTE: LOW INDICATES LESS THAN 20 KILOTONS.

underground. The 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.

If a device was emplaced too deep 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 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. Figure 2.1 shows a typical subsidence crater.

2.1.2 Tunnel-Type

A tunnel-type nuclear detonation was intended to be completely contained. The nuclear device was emplaced in a mined opening at a depth which usually contained the detonation. Chimneying of broken rock to the surface seldom occurred primarily because a layer of rhyolite rock on the surface of Rainier Mesa and the granite rocks of Area 15 were more competent than alluvium in Frenchman and Yucca Flats. A tunnel emplacement might be at the end of a single horizontal tunnel into a mountain or mesa, in one tunnel of a complex of horizontal tunnels used

Figure 2.1 A typical subsidence crater.

for experiments and other nuclear detonations, in a horizontal tunnel from the bottom of a vertical shaft, or in an opening of variable size and shape mined from a tunnel or the bottom of a shaft. Figure 2.2 shows the portal of a typical DOD tunnel complex.

2.2 DIAGNOSTIC TECHNIQUES

The major advantage of underground testing was containment of radioactive material. One of the major disadvantages was increased difficulty in determining characteristics of a detonation. Photographing a fireball growing in the atmosphere was no longer possible. Samples of a radioactive cloud for diagnostic purposes no longer could be obtained by sampling aircraft. Measurements of thermal radiation, nuclear radiation, and blast were complicated by the confined underground structures. These disadvantages were overcome by developing new diagnostic techniques, some of which are discussed below.

2.2.1 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 the measurement signals to the surface where electronic equipment, film, and magnetic tape recorded the signals.

The 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 was necessary to acquire and refine these capabilities.

Figure 2.2 Portal of typical DOD tunnel complex.

2.2.2 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 to the atmosphere after samples were collected.

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

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.

2.2.3 Line-of-Sight (LOS) Pipes

Most of the DOD shaft-type detonations included LOS pipes from the device emplacement to the surface. These pipes allowed effects experiments to be conducted as well as measurement of radiations from the detonations.

However, the LOS pipes to the surface required closure systems as did the radiochemical sampling pipes, and use of LOS pipes to the surface also resulted in some releases of radioactive effluent to the atmosphere. Thus, the frequency of DOD shaft-type events, including use of these pipes to the surface, decreased for several years until containment techniques improved, but use of horizontal LOS pipes in underground tunnel complexes became frequent and a valuable weapons effects testing system.

2.3 EFFECTS EXPERIMENTS

Weapons effects experiments were the primary reason for conducting DOD underground nuclear detonations. The effects of blast, heat, and radiation from a nuclear detonation in the atmosphere had been studied extensively. Structures, equipment, and materials had been exposed to atmospheric detonations, and military hardware also had been exposed to underwater detonations. Underground testing provided an opportunity to study effects of ground shock and motion, and, of particular importance, the effects of a nuclear detonation environment on equipment and materials at a simulated high altitude.

The simulation of a high-altitude detonation was made possible by enlarging and improving the LOS pipe system discussed in section 2.2.3. Large-diameter pipes hundreds of feet long were constructed underground with the device emplaced at one end of the pipe. An access tunnel sometimes was constructed parallel or at an angle to the LOS tunnel, and crosscuts connected the two at intervals. Hatches allowed access to the LOS pipe and sealing of the pipe. Equipment and materials were installed at locations within the LOS pipe. The atmosphere in the LOS pipe was reduced in pressure by vacuum pumps, to simulate a high altitude, before the detonation. Thus, testing of weapons effects was extended from atmospheric and underwater to underground and at simulated high altitudes.

2.4 CONTAINMENT FEATURES AND PROBLEMS

Completely containing radioactive material underground while accomplishing diagnostic measurements and effects tests 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 caused by diagnostic and experiment structures. Under certain conditions, particularly the presence of clay, high water content of rock near the detonation point resulted in greater stress toward the surface which sometimes caused containment failures. These 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.

2.4.1 Shaft 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 was used in place of 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. Fast-gate 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 imbedded in concrete and epoxy, which effectively prevented 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 imbedding 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 and 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 resolved by investigations of proposed detonation locations and application of detailed site selection criteria.

2.4.2 Tunnel 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 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. Farther toward the portal, and before entering the main tunnel in a complex with more than one test location, 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.

Generally, the sandbag plugs became solid sand backfill hundreds of feet long. Stemming was used that had ground-matching characteristics, such as matching transmission of shock waves and other properties so that differences from surrounding ground would not contribute to containment failure. The blast door evolved into a massive overburden (equivalent) plug separating test location tunnels from the main tunnel. The plug typically was 20 to 30 feet of keyed concrete with a large steel door containing a smaller access hatch, and was designed to withstand overpressure up to 1000 psi.

Use of the LOS pipe in tunnel events necessitated development of additional containment and closure systems. The LOS pipe tunnel and its access tunnels were separated from the main tunnel by the overburden plug. Additional containment and closure systems were for protection of the LOS pipe and its experiments as well as preventing release of effluent to the surface.

Generally, the tunnel volume outside of the pipe was filled by stemming, grouting, or other means to facilitate containment, while the inside of the pipe and its experiments were protected by closure systems. Various systems were in use including compressed air or explosive-driven gates and doors which closed off the LOS pipe from the detonation within a small fraction of a second after detonation time. Beginning with the DOOR MIST event, one of these enclosures was the Tunnel and Pipe Seal (TAPS) unit. The TAPS unit usually was 500 to 550 feet from the zero point.

The same gas blocking techniques 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 overburden plug. Utility pipes, such as for compressed air, that passed through stemming and plugs also were sealed by closure systems.

Containment systems evolved to the point that release of detectable radioactivity to the atmosphere has seldom occurred.

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 visitors. When security-classified material was 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 project manager for safety of personnel underground. From 1962 forward, Radsafe log books and tunnel log books 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, 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.

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 radex area.

All persons entering radex areas were logged on Area Access Registers. Names and organizations represented were listed. Radiation exposures for the year and quarter were listed upon entry and added to self-reading pocket dosimeter measurements upon exit. This was to assure that personnel approaching radiation exposure guide limits would not be allowed to enter radex areas and 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 if necessary, and decontamination was accomplished.

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 preevent 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.

When classified materials, including the nuclear device, were brought into the area for emplacement, the Laboratory which provided the device controlled access to the area with assistance from security force personnel 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 the 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 the NTS. Administered by REECo, the safety program enjoined all NTS personnel to conduct operations safely, and was exemplified by the signs on the portal of a typical DOD tunnel complex as shown in Figure 2.2, including "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, 2.7 "Radiological Safety Procedures."

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. The Draeger multi-gas detector and MSA explosimeter were used to detect such gases. The Fyrite or J&W oxygen indicators were used to determine the 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 breathing air 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 primary written procedures and implementation methods used at the NTS from 1967 through 1968.

2.7.1 U.S. Atomic Energy Commission, Nevada Test Site Organization - Standard Operating Procedure, 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 United States Public Health Service (PHS) 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 3G (alpha)
- Eberline PAC 4G (alpha)
- Eberline PAC 1SA (alpha)
- Jordan AGB-500-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 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 non-radioactive materials, such as beryllium, through use of an emission spectrograph and by wet chemistry procedures. A spectrophotometer was used to analyze other materials.

D. Monitoring of Personnel Exposures

The Du Pont type 301-4 film packet was replaced with the NTS combination personnel dosimeter and security credential holder 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 Du Pont type 556 film packet, a fast neutron packet, an 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 Du Pont 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 2.3.

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

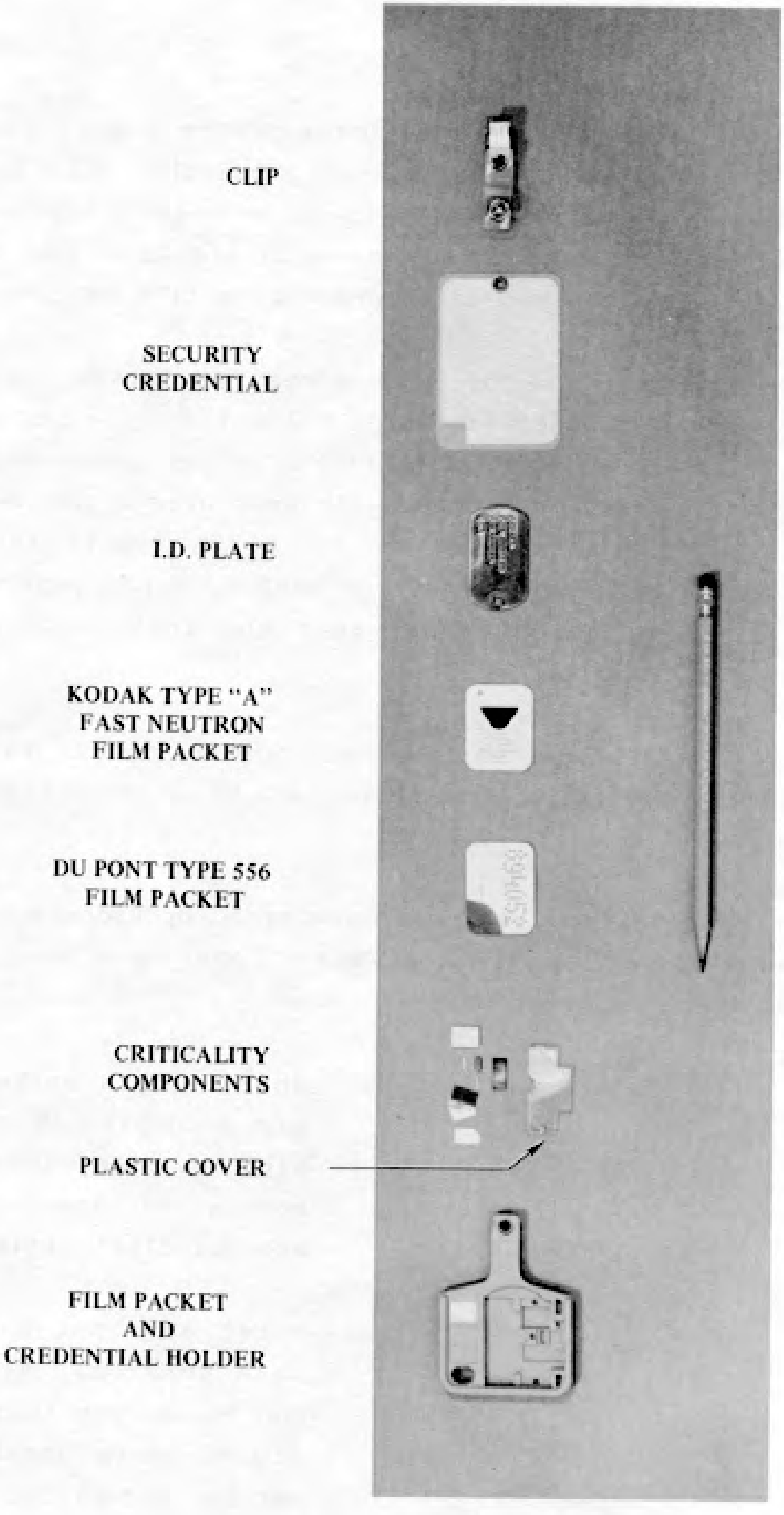

Figure 2.3 NTS combination personnel dosimeter and security credential holder.

daily NTS radiation exposure report for use until results of film packet processing were included. Pocket dosimeter readings were only 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 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.

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. 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 radiation 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 1967 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, hardwire-linked, remote area gamma radiation monitoring (telemetry) system, designed and modified by Radsafe and produced by Victoreen Instrument Corporation. It consisted of a probe which used a Neher-White radiation sensing element, hardwire communication to the readout console (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 $\pm$ 15 percent over the temperature range of -10°F to 150°F.

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 hardwire-linked to a field trailer where signal data was 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 hardwire 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 checkout, in addition to use during and after the 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, and 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 appropriate distances from SGZ which varied with device yield and predicted wind direction (see Figures 2.4 and 2.5). Variable numbers of detectors 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 locations throughout NTS (Figure 2.6). The large number of remaining channels was available for additional detector locations and substitute channels. Event-related telemetry detectors operated from zero time until it was determined that release of

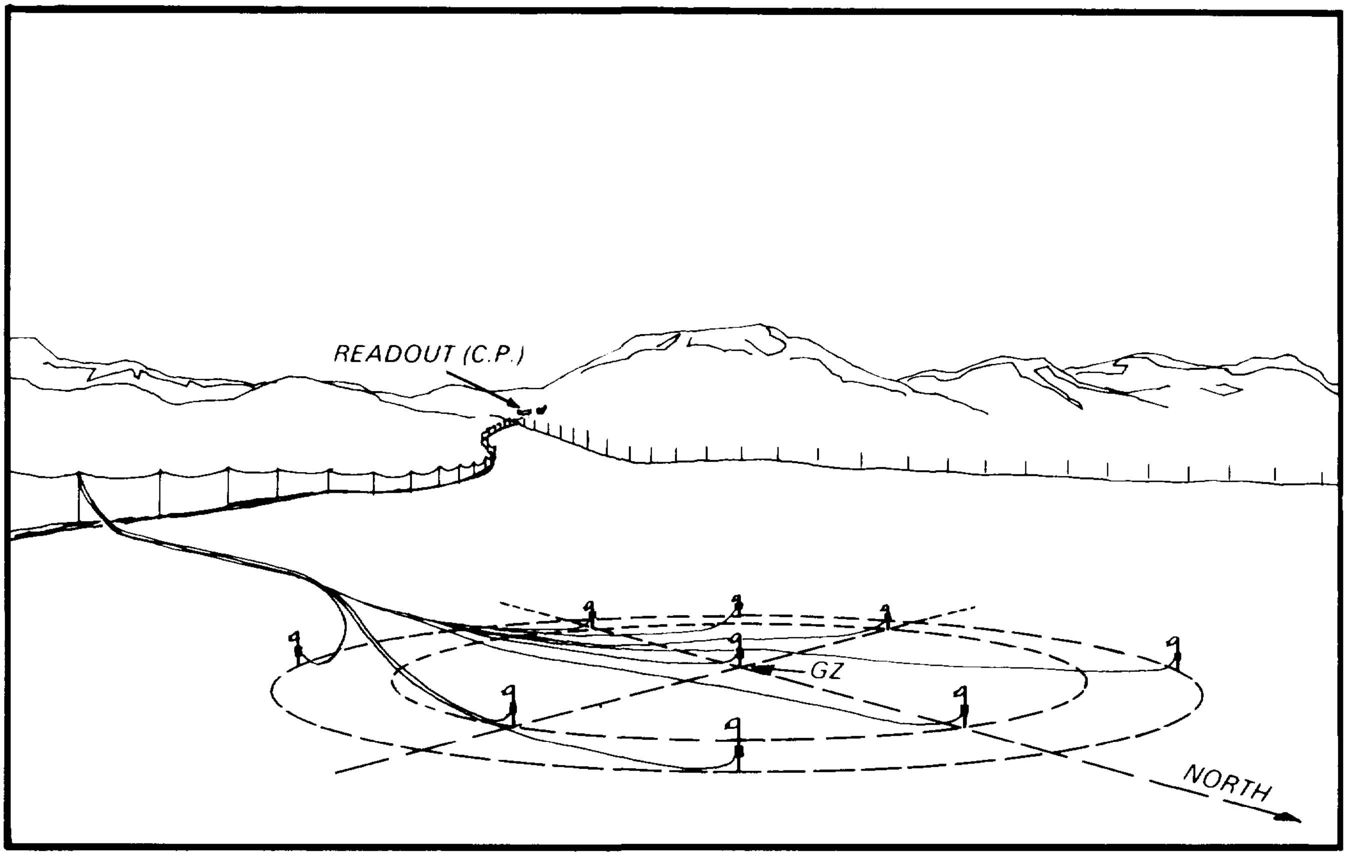

Figure 2.4 Typical remote radiation detection monitoring system for shaft type emplacement site.

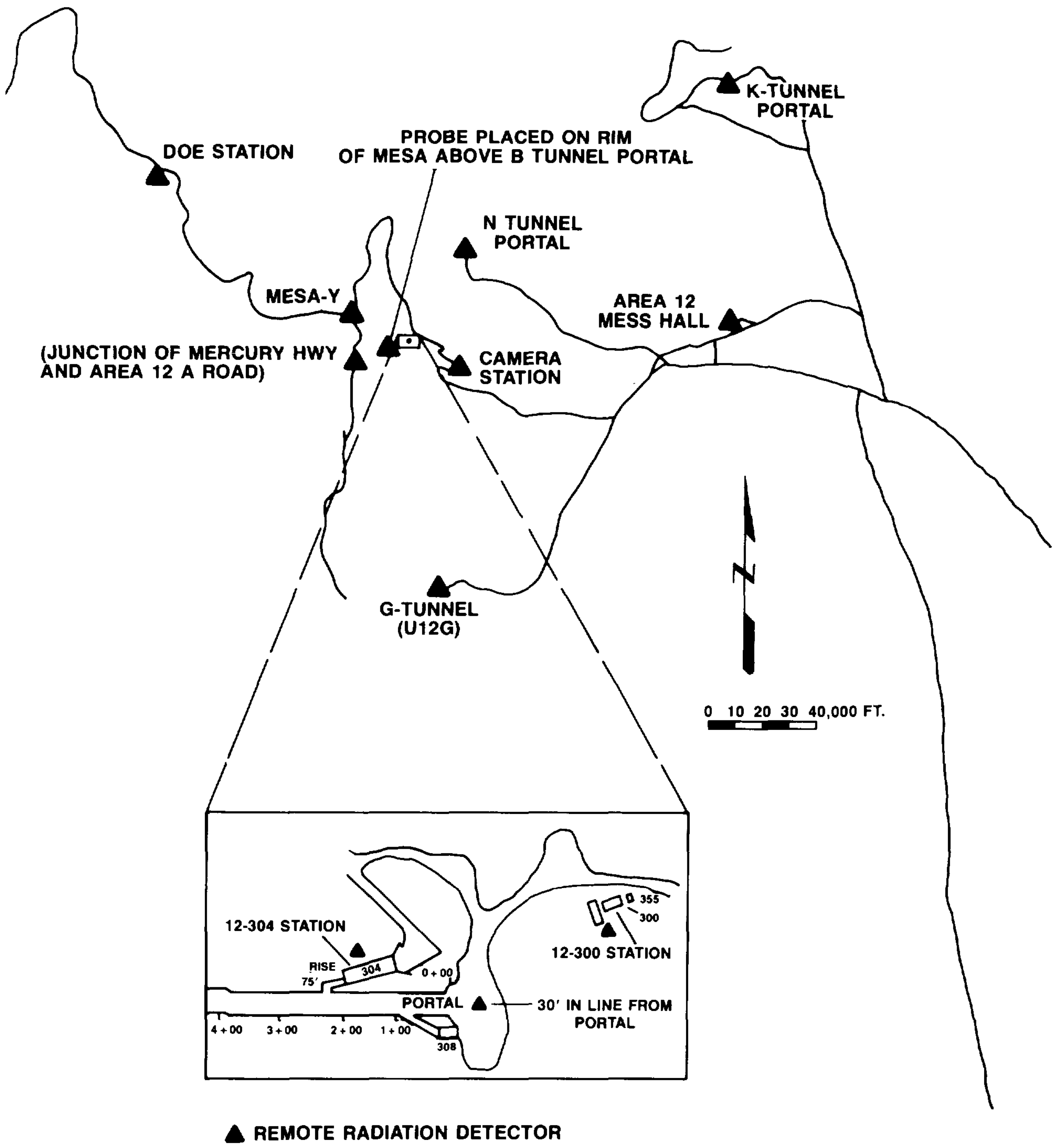

Figure 2.5 Typical remote radiation detection monitoring system for tunnel-type emplacement site.

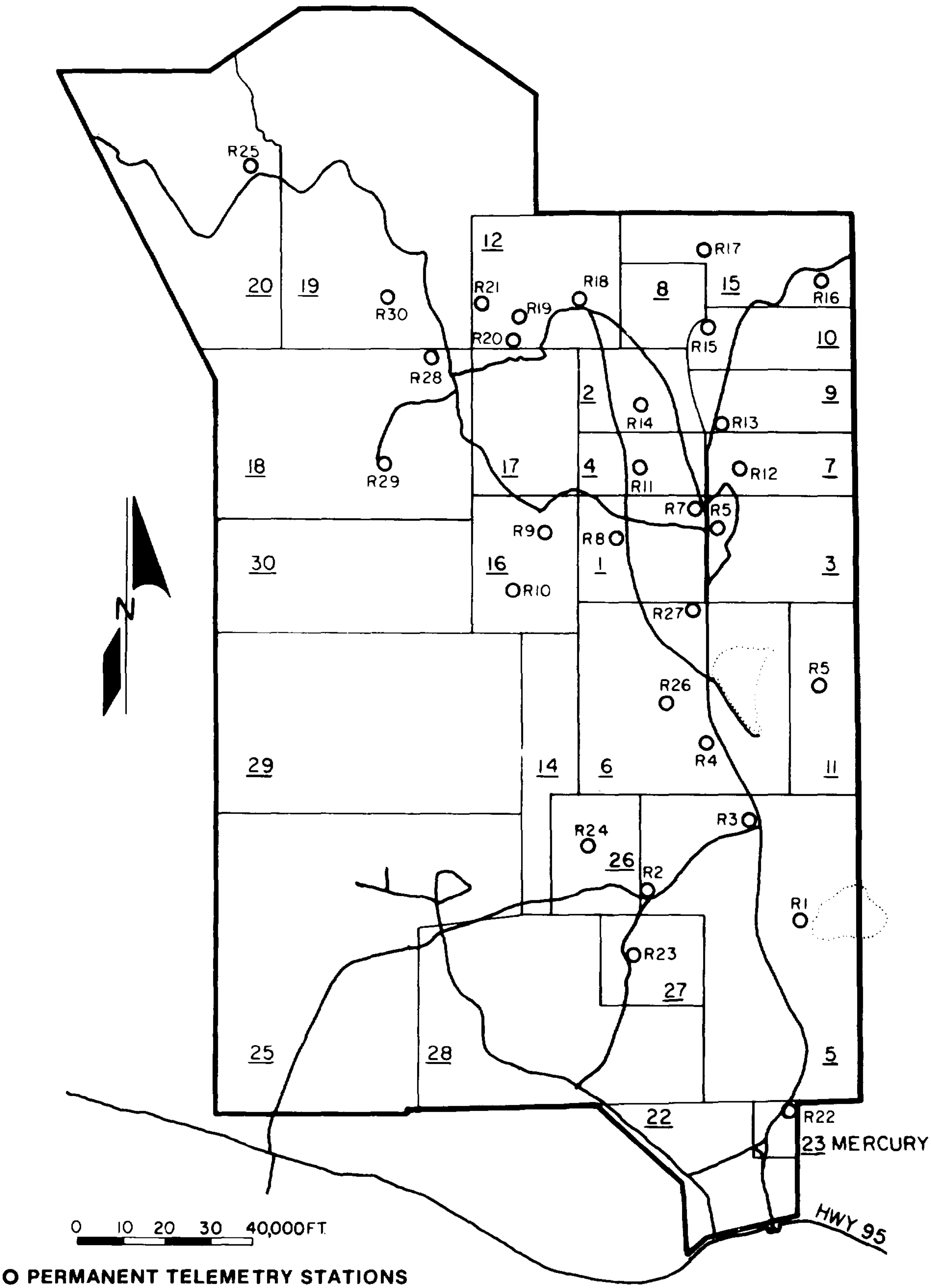

Figure 2.6 Typical permanently established remote radiation detector stations operated continuously throughout the NTS.

radioactivity probably would not occur, or until any released radioactivity had decayed to near-background levels at the telemetry stations. For some events, readout locations were positioned near the FCP or at locations where telephone lines were available, in addition to those events where readouts were located at CP-2.

Radiation telemetry data were supplemented with information collected by 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 units remained in position until drillback operations were completed or the Test Group Director authorized removal of the units.

2.9 AIR SUPPORT REQUIREMENTS

The AFSWC provided direct support to NTSO for DOD underground tests, and other Air Force organizations provided support under AFSWC control as described in section 1.4.3 of this report. However, less air support was required 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 1962, Air Force cloud sampling and cloud tracking aircraft generally were not required, except 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 PHS monitor. The PHS 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 PHS 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 photographers and Radsafe monitors.

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

Radsafe support facilities had been established about 20 miles southeast of Mercury at ISAFAF 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 anticontamination clothing and respiratory protection equipment, monitored aircraft and personnel after events, decontaminated personnel, and assisted ground crew personnel with decontamination of aircraft.

Figures 2.7 through 2.9 show decontamination and monitoring of typical B-57 cloud sampling aircraft used from 1962 until the type of sampling aircraft was changed.

Aircrews departing from contaminated aircraft removed anticontamination clothing and equipment at the radsafe facility, showered, and were monitored to assure complete decontamination before they dressed in regulation clothing and were released. Ground crew personnel who removed particulate and gaseous cloud sample collection media from aircraft or who participated in aircraft decontamination were subject to the same personnel decontamination procedures.

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 Director's FCP established for a particular under-

Figure 2.7 Air Force personnel decontaminating a B-57 cloud sampling aircraft.

Figure 2.8 Air Force and Radsafe personnel monitoring a B-57 after decontamination.

Figure 2.9 Radsafe monitor measuring exposure rate on a B-57 aircraft.

ground 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

DOOR MIST EVENT

3.1 EVENT SUMMARY

DOOR MIST was a DOD-sponsored underground test detonated at 0930 hours Pacific Daylight Time (PDT) on 31 August 1967 with a yield less than 20 kt. The device was detonated in tunnel U12g.07 at a vertical depth of 1,463 feet and approximately 5,655 feet in from the portal (Figure 3.1). The objective of this test was to determine the response of materials and equipment to a nuclear detonation environment. Government agencies and contractors conducted 11 projects to obtain the desired weapons effects information.

Stemming and containment failures occurred and resulted in damage to, and contamination of, the experiments. Effluent was released to the atmosphere, and minor levels of radioactive effluent were detected offsite.

3.2 PREEVENT ACTIVITIES

3.2.1 Responsibilities

Safe conduct of all DOOR MIST 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,

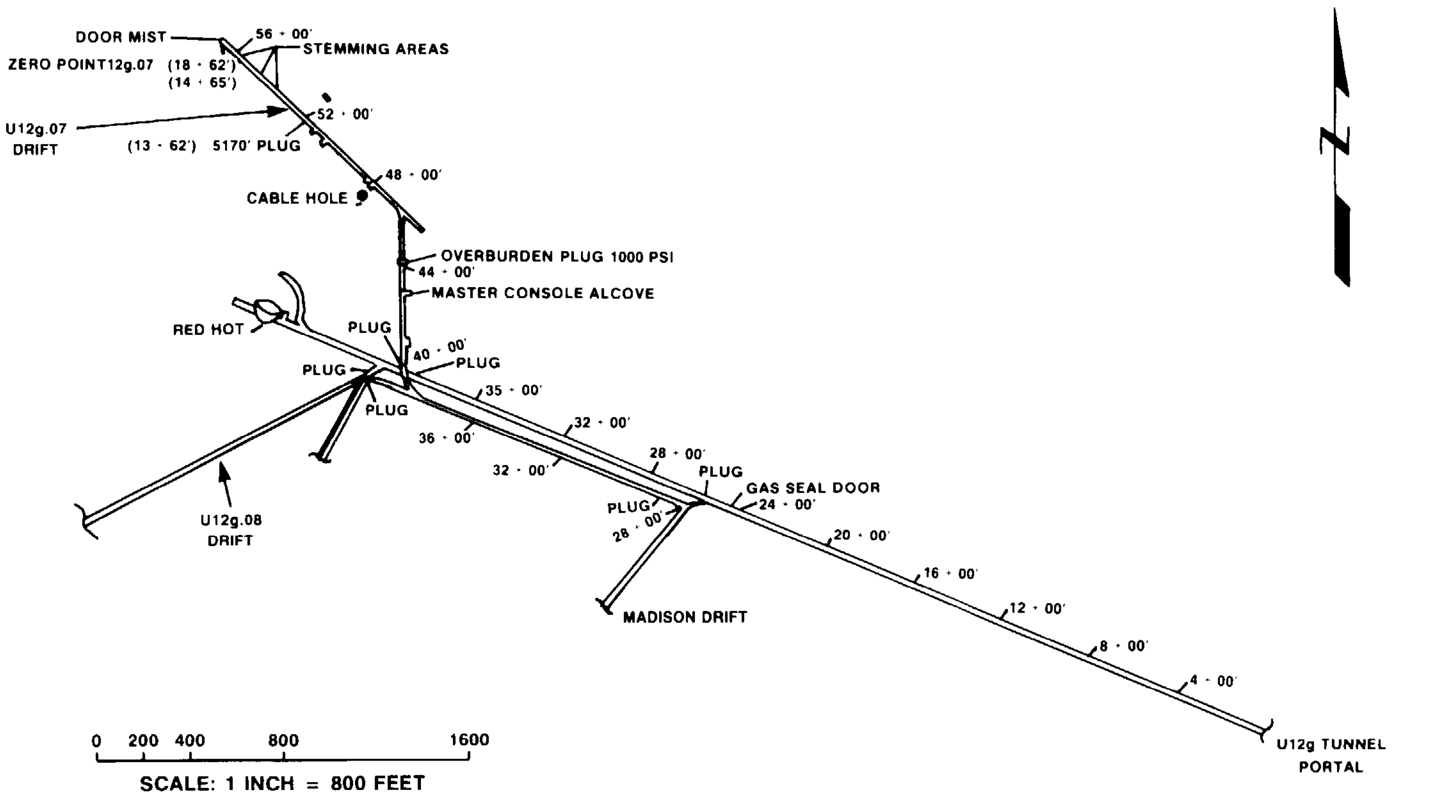

Figure 3.1 DOOR MIST event - tunnel layout.

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

Because LASL fielded the device, 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 the device was detonated. 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."

3.2.2 Planning and Preparations

A. Tunnel Facilities Construction

The DOOR MIST experimental facility was installed as designed. It consisted of an 800-foot-long vacuum pipe with two test chambers. Test chamber No. 1 was installed at the end of the pipe 800 feet from the device, while test chamber No. 2 was located 565 feet from the device.

B. Radiological Safety Support

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

Detailed radiological safety reentry plans were given to participating agencies prior to the test event. 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. All RAMS units and air sampling units were installed a minimum of five days prior to scheduled device detonation.

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

Thirty-seven remote telemetry radiation monitoring system units provided aboveground and underground coverage for the DOOR MIST event as shown in Table 3.1.

Eleven air sampling units were located as shown in Table 3.2.

Table 3.1. DOOR MIST event RAMS unit locations.

Station	Location (distances are from portal)
	ABOVEGROUND
1	38 feet at 311°23' azimuth
2	138 feet at 160°45' azimuth
3	138 feet at 160°45' azimuth
4	281 feet at 31°23' azimuth
5	496 feet at 71°34' azimuth
6	438 feet at 123°30' azimuth
7	366 feet at 163°07' azimuth
8	223 feet at 245°55' azimuth
9	255 feet at 334°00' azimuth
10	1,374 feet at 14°56' azimuth
11	1,565 feet at 50°40' azimuth
12	1,445 feet at 81°40' azimuth
13	1,446 feet at 113°30' azimuth
14	1,235 feet at 195°01' azimuth
15	1,778 feet at 253°15' azimuth
16	2,687 feet at 288°00' azimuth
17	2,048 feet at 330°32' azimuth
18	3,779 feet at 264°41' azimuth
19	4,470 feet at 279°59' azimuth
20	4,795 feet at 293°01' azimuth
21	4,635 feet at 300°44' azimuth
22	4,732 feet at 301°05' azimuth
23	4,672 feet at 301°35' azimuth
24	4,611 feet at 302°06' azimuth
25	4,709 feet at 302°22' azimuth
26	5,811 feet at 304°29' azimuth
26a	5,378 feet at 308°31' azimuth
	UNDERGROUND
27	5,098 feet in the 07 drift
28	4,888 feet in the 07 drift
29	4,458 feet in the 07 drift
30	4,358 feet in the 07 drift
31	3,800 feet in the reentry drift
32	2,500 feet in the main drift
33	2,400 feet in the main drift
34	1,200 feet in the main drift
35	50 feet in the main drift
36	4,676 feet in the 08 drift

Table 3.2. Air sampling unit locations.

Station Number	Distance and Azimuth from Portal
1	50 feet at 111°
2	281 feet at 31°23'
3	496 feet at 74°13'
4	438 feet at 123°30'
5	366 feet at 163°7'
6	138 feet at 160°45'
7	510 feet at 304°30'
8	4,635 feet at 300°44'
9	4,732 feet at 301°5'
10	4,611 feet at 302°6'
11	4,709 feet at 302°22'

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 test area were required to stop at muster or control stations for issue of stay-in badges, and issue or 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 Schedule of Events," 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

Event photo documentation was performed by Army Pictorial Service (APS) personnel in a USAF UH-1F aircraft. An additional USAF UH-1F and crew provided dual support coverage by performing aerial security sweeps prior to the event and then being put on emergency standby for the Test Manager's use if needed. Cloud sampling was provided by PHS personnel in a Turbo-Beechcraft with an additional Turbo-Beechcraft on standby at McCarran Airport in Las Vegas. A USAF U-3A aircraft with USAF crew and PHS technical personnel, the EG&G/Nevada Aerial Tracking System (NATS) aircraft, and the EG&G/Aerial Remote Monitoring System (ARMS) aircraft were used for cloud tracking.

3.2.3 Late Preevent Activities

Because this event was originally scheduled for 30 August 1967, the first security sweep was conducted between 1905 and 2230 hours on 29 August. Shortly after this sweep was completed, early in the morning hours of 30 August, personnel from SC, Stanford Research Institute (SRI), EG&G, LASL, and DOD made final instrumentation checks at the portal, in the tunnel, and at the Rainier Mesa trailer park. They loaded film and checked closed circuit television cameras.

A security sweep was conducted between 0100 and 0149 hours on 30 August. Permission to arm the device was granted at 0740 hours and arming was complete by 0840 hours. However, at 0852, zero time was rescheduled for 0930 hours because a storm between Mercury and Las Vegas was causing problems with power lines. At 0925 hours, the decision was made to postpone the test for 24 hours, and a readiness briefing was scheduled for 1500 hours on 30 August. The arming party was given permission to disarm the device at 0930 hours, and completed this task by 1012 hours.

A security sweep was conducted from 1930 to 2100 hours on 30 August.

3.3 EVENT-DAY AND CONTINUING ACTIVITIES

The final security sweep began at 0030 hours on 31 August 1967, and was completed at 0115 hours.

All projects were rechecked to assure that instruments were functioning properly. The arming party entered the area at 0610 hours. Permission to arm the device was granted at 0737 hours, arming procedures were completed, and the arming party was clear of the area by 0815 hours.

DOOR MIST zero time was 0930 hours PDT on 31 August 1967.

3.3.1 Telemetry and Radioactive Effluent Release Situations

At approximately 0945 hours an uncontrolled release began through instrumentation cables. The first telemetry reading outside the underground complex was 0.5 mR/h at 0945 hours at the surface cable hole, which increased to a maximum of 30 R/h at 1105 hours, and then decreased to 3 R/h by 1530 hours. This release consisted primarily of noble gases.

A second uncontrolled release, this time from the tunnel portal, started at 1045 hours when a reading of 0.1 mR/h was recorded. This reading increased gradually until a maximum of 40 R/h was reached at 1217 hours. This release consisted of noble gases and radioisotopes of iodine and ruthenium.

At 1300 hours, a controlled release took place when tunnel ventilation was turned on and effluent was passed through a filter system. This controlled release situation continued until 1500 hours.

Shortly after 1530 hours, a third uncontrolled release occurred from the tunnel portal. It, too, consisted of noble gases, iodines, and radioisotopes of ruthenium. At 1730 hours, the tunnel ventilation system again was turned on and effluent was released through the filter system until H+72 hours. Radiation readings continued to decrease steadily thereafter.

3.3.2 Initial Radiation Survey and Reentry Activities

The initial radiation survey of Rainier Mesa trailer park was performed from 1036 hours to 1117 hours on D-day. When radiation readings reached 15 mrad/h and 9 mR/h at Stake 12R-6 (1110 hours) about 2 miles southwest of the portal, the reentry team members put on respiratory protection equipment and completed the survey.

Film, magnetic tape, and instrument recovery from Rainier Mesa trailer park was conducted between 1130 and 1220 hours. The reentry teams were dressed in anticontamination clothing and had appropriate respiratory protection equipment available if needed. The maximum exposure rate detected was 500 mR/h at the trailer park approximately 500 feet south from the downhole cables at 1150 hours. A second radiation survey team accompanied the recovery party.

Venting prohibited immediate tunnel reentry. Therefore, the initial survey of U12g access roads and tunnel was postponed until 1 September.

3.3.3 Cloud Tracking and Sampling

A. <u>PHS Aircraft Mission</u>

A USAF U-3A aircraft flown by a USAF pilot with two PHS monitors on board tracked the effluent. Winds on D-day were light and variable, moving the radioactive effluent slowly to the north-northwest. By the time the cloud had moved to offsite populated areas, it was diffused over a large area and most of the short-lived radionuclides were not detectable.

B. ARMS Aircraft Mission

At 1450 hours, a request was made for the ARMS aircraft to perform a cloud tracking and sampling mission. The aircraft departed Las Vegas at 1506 hours and intercepted the effluent cloud over Kawich Valley at 1600 hours. Perimeter tracking was successful, resulting in two complete circumnavigations of the cloud. The maximum count rate was greater than 100,000 cps at 10,000 feet MSL over the portal. The mission was terminated at 1940 hours.

C. NATS Cloud Tracking Mission No. 1

The NATS aircraft departed Las Vegas, Nevada, at 0610 hours on 1 September 1967. Initial contact with the cloud occurred at 0715 over Railroad Valley. Spotty and intermittent count rates prevented complete circumnavigation and good cloud edge delineations. Upon mission completion at 1130 hours, the aircraft landed at Reno, Nevada.

D. NATS Cloud Tracking Mission No. 2

The NATS aircraft departed Reno, Nevada, at 1302 hours on 1 September 1967. Initial contact with the cloud was made at 1350 hours over Austin, Nevada. Intensity levels were weak and occasionally intermittent; however, count rates greater than 100,000 cps were detected at 9,500 feet MSL over the DOOR MIST portal. The aircraft landed at Las Vegas at 1730 hours after completing its mission.

3.4 POSTEVENT ACTIVITIES

3.4.1 Portal Survey

The initial survey of the U12g access roads and portal area was conducted from 1040 to 1300 hours on 1 September 1967. The maximum reading at the portal was 1000 mR/h. After this survey, no further attempts were made to reenter U12g.07 until 5 September.

The ventilation system to the 07 drift was not working; however, ventilation was remotely activated to the 08 drift. The 08 drift was a mined but unused drift past the 07 drift entrance in the U12g tunnel complex. Ventilation through the tunnel to the 08 drift would allow access to the 07 drift entrance.

3.4.2 Tunnel Reentry

On 5 September at 1655 hours, a team dressed out in appropriate anticontamination clothing and respiratory protection equipment entered the tunnel to the gas seal door. No tunnel damage was noted to this point. This team then began opening the manway door in the gas seal door, with successful completion of the task occurring at 1802 hours. When the door was opened, team members observed water approximately one foot deep extending 75 to 100 feet beyond the door to the curve in the main drift. A maximum radiation intensity of 10 R/h was detected at the gas seal door. After obtaining radiation measurements, and checking for toxic gases and explosive mixtures, the team exited the tunnel at 1812 hours.

On 6 September at 1015 hours, a team (appropriately dressed for entry into a radex area) entered the tunnel to remove bolts from the gas seal door and set up a pump to remove water from the area. They exited the tunnel at 1037 hours. Some problems with a ventilation fan occurred later in the day, but an auxiliary fan was started in order to maintain continuity. The primary ventilation fan was back in operation on 8 September. No tunnel entries were allowed on 9 and 10 September.

A reentry party attempted to reach the overburden plug on 12 September. They were dressed in anticontamination clothing and provided with respiratory protection equipment as on previous reentries. They entered the tunnel at 1405 hours and proceeded toward the overburden plug, measuring radiation intensities, toxic gases, and explosive mixtures as they traveled. Approximately 550 feet into the 07 drift, they obtained a radiation reading of 20 R/h. The party immediately withdrew from the area and exited the tunnel at 1435 hours. No further reentries were made until 19 September when a reentry team walked out the 08 drift, which was found to be in good condition.

On 20 September at 1030 hours, team members dressed in full anticontamination clothing and wearing McCaa-supplied air breathing apparatus proceeded toward the overburden plug. Approximately five feet before reaching the plug, their radiation detection instruments measured 12 R/h. The floor of the 07 drift had become crusty and very soft. Considerable steam was present and bubbles were coming from the manway door. The team exited the tunnel at 1130 hours without proceeding further into the drift.

Between 20 September and 3 October, various work parties performed tasks necessary to open the overburden plug door. These reentry operations were generally for extremely short periods of time. The manway door was opened at 0930 hours on 3 October. At that time, a contact reading of 6 R/h was measured at the door, as well as a personnel exposure rate of 1.5 R/h, 500 ppm carbon dioxide, and 200 ppm carbon monoxide. No explosive mixtures were detected.

The first reentry beyond the overburden plug began at 1025 hours on 5 October. Upon exiting the tunnel at 1110 hours, the team reported the following conditions as recorded in the "Field Support Report:"

1. Radiation intensity was approximately 5 R/h at the overburden plug manway door.

2. There were eight inches of water on the tunnel floor.

3. Fifty feet beyond the plug, the radiation intensity was 3 R/h and carbon monoxide was 1200 ppm.

4. Debris was estimated to be four feet deep across the tunnel floor.

5. All the lagging was burned out beyond the overburden plug.

6. The temperature was in excess of 130°F.

The reentry team aborted the reentry mission because of the condition of the tunnel. At this time, all reentry and experiment recovery operations became concentrated on mining through from the U12e.04 drift.

3.4.3 Postevent Mining (U12e.04 Drift to U12g.07 Drift)

Numerous reentries made into the G tunnel complex after the DOOR MIST event indicated that the tunnel was extensively damaged on the zero point side of the overburden plug. No lagging remained between the sets, rubble and spalled rock were on the tunnel floor, and high temperatures were encountered. Explosive mixtures, toxic gases, and high radiation fields were encountered as well. Even after partial ventilation of the tunnel, it was determined that the presence of debris and existence of substantial radiation levels precluded experiment recovery through the g.07 drift.

In order to effect experiment recovery, the decision was made to mine a reentry tunnel from the existing U12e.04 personnel drift to the U12g.07 drift (Figure 3.2). Rehabilitation of the e.04 drift was conducted between 15 and 27 September, with mining toward U12g.07 beginning on 28 September. This recovery drift intersected the DOOR MIST drift at the Tunnel and Pipe Seal (TAPS) No. 1. Two branch drifts, the containment assessment drift and the experiment recovery drift, were mined paralleling the DOOR MIST drift. Crosscut drifts were mined at appropriate stations of interest (Figure 3.3).

On 1 November 1967, the concrete plug surrounding TAPS No. 1 became visible in the working face. Contact readings at this location were 1 R/h with a personnel exposure rate of 25 mR/h. After the round was mucked out, the exposure rate increased to 50 mR/h at the face.

During graveyard shift on 3 November, the reentry heading broke into the g.07 drift on the portal side of the TAPS No. 1 plug. Considerable steam was observed coming from the g.07 drift, and work in the heading was stopped until a procedure could be developed for continuing. A survey of the muckpile indicated an exposure rate of 50-100 mR/h and a temperature of 130° F. After the round was mucked out on 6 November, the exposure rate in the g.07 drift was found to be 4 R/h.

Crosscut No. 2, mined from the containment assessment drift to the zero point side of TAPS No. 2, broke into the g.07 LOS drift on 8 November. Contaminated water was noted seeping through the muck pile into the containment assessment drift. A nauseating odor also was noted, but could not be identified. Work was

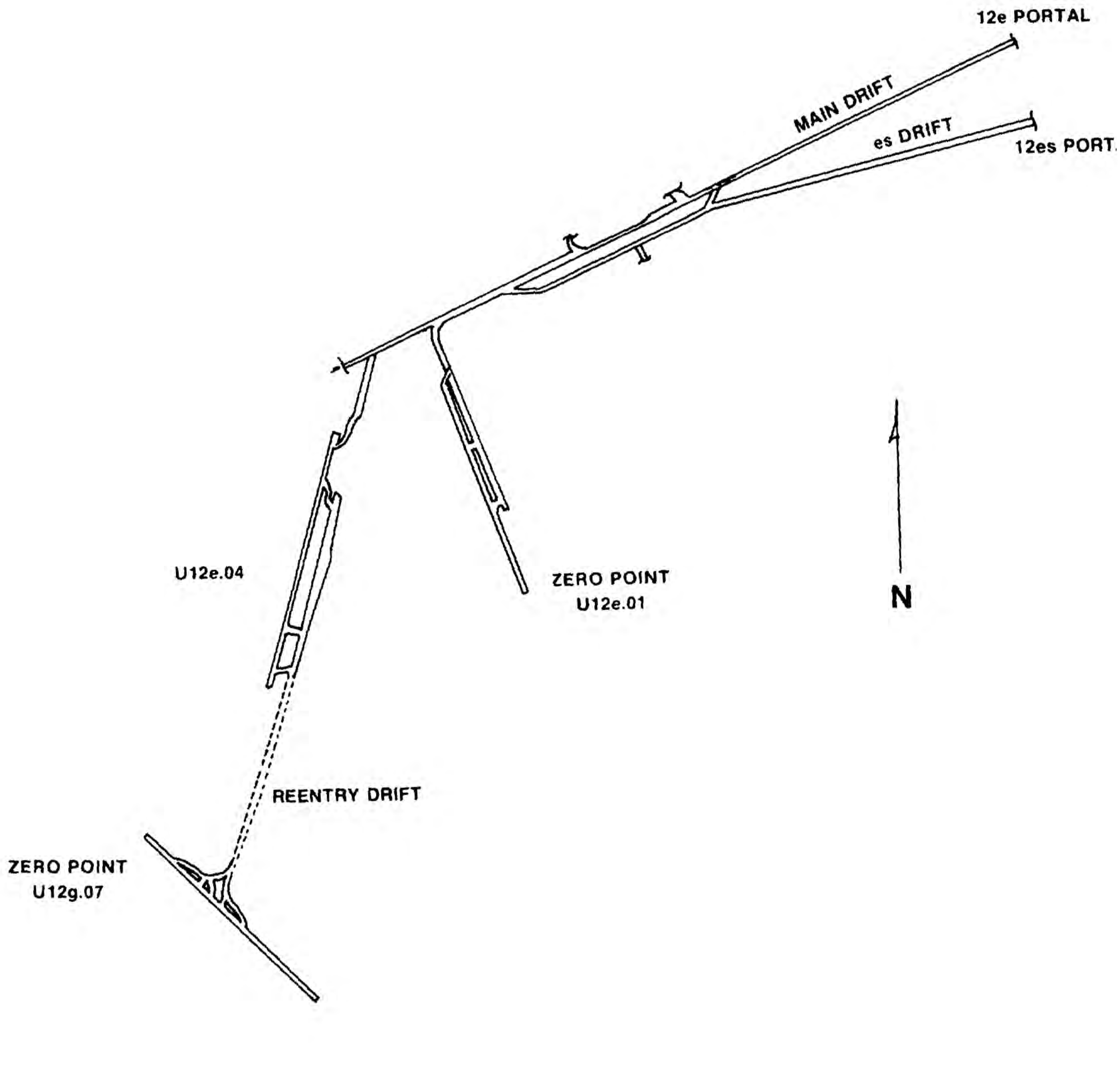

Figure 3.2 DOOR MIST event - planned reentry through U12e.04.

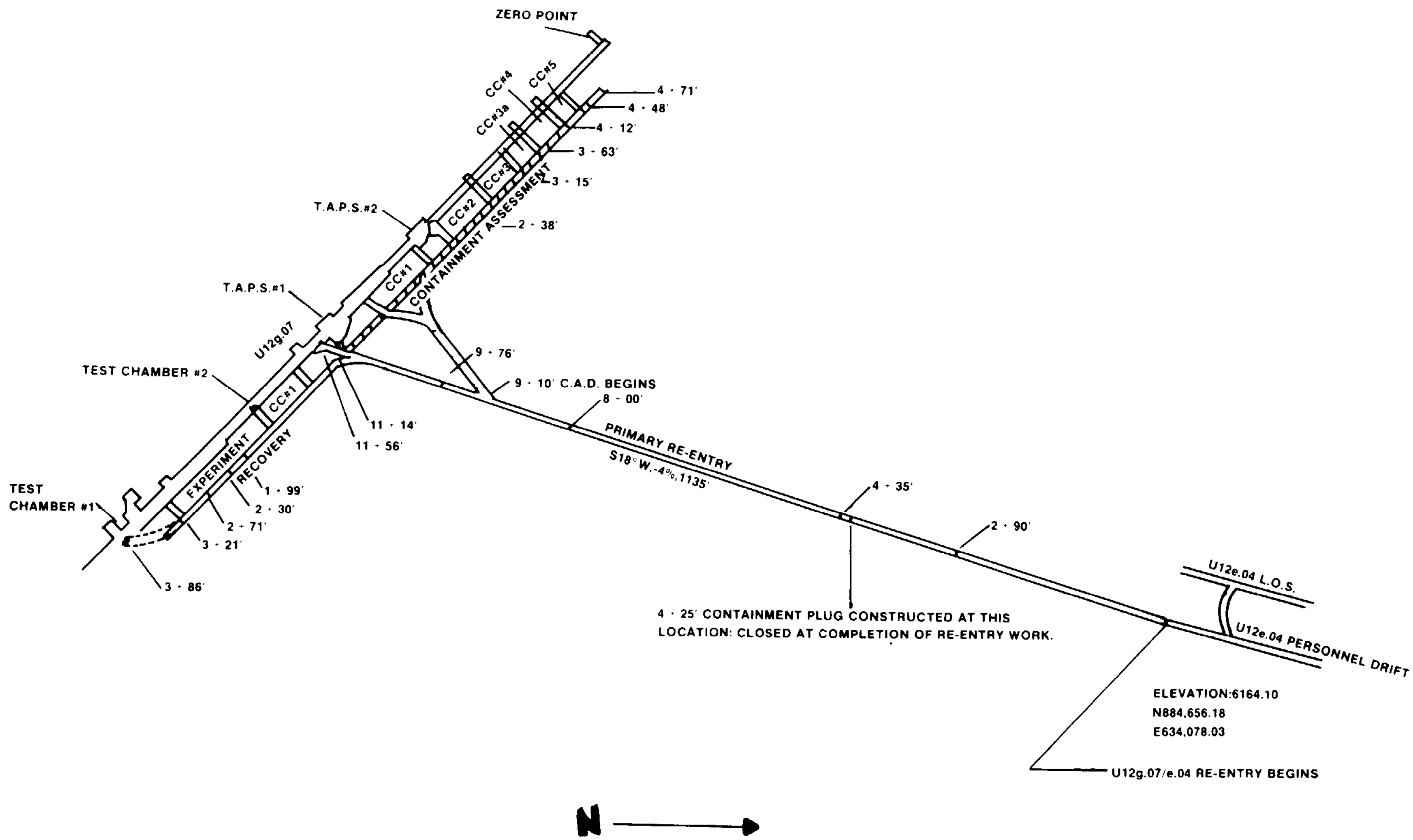

Figure 3.3 DOOR MIST event - postevent tunnel layout.

stopped in crosscut No. 2 until 13 November when the previously-fired round was mucked out. Sand was visible in the face and the exposure rate was up to 1.8 R/h in the heading.

With the face in crosscut No. 3 at 0 + 20 feet, a probe hole was drilled ahead to intersect the LOS drift. A gamma survey of this probe hole on 16 November indicated the following readings:

Face plus 10 feet	100 mR/h
Face plus 20 feet	500 mR/h
Face plus 26 feet	1 R/h
Face plus 28 feet	2 R/h

Mining in crosscut No. 3 continued until 18 November when miners uncovered a seam with a radiation intensity of 50 R/h at contact, with an exposure rate of 10 R/h. All personnel were cleared from this area and no further work was conducted in this crosscut.

Several other crosscuts were mined from the containment assessment drift to the LOS drift, all of which encountered high exposure rates and bad ground. Numerous probe holes were drilled from the containment assessment drift and its crosscuts to determine radiation intensities and composition, cavity dimensions, and other containment-related parameters.

On 17 November, a turnout to the right from the reentry heading toward the portal side of TAPS No. 1 broke into the manway. On 20 November, an entry was made into the LOS pipe from this point, with the reentry party going to scientific station No. 2. The exposure rate was 7 R/h approximately 50 feet from the entrance point into the LOS pipe and 5 R/h at scientific station No. 2.

On 28 November, another reentry was made into the LOS pipe and some scientific samples were recovered. The maximum exposure rate encountered during the reentry was 4 R/h; no toxic gases or explosive mixtures were detected. Radiation levels decreased as the team progressed toward scientific station No. 1, with an exposure rate of 500 mR/h being detected at the test chamber.

On 30 November, the experiment recovery drift was started off of the left rib of the reentry drift. Crosscut No. 1 was started off this heading toward test chamber No. 2 on 8 December. This crosscut broke into the g.07 LOS drift on 13 December. The exposure rate at the junction of the crosscut and the LOS drift was 5 R/h; ventilation was good with the air flow toward U12g.07.

Mining in the experiment recovery drift continued, breaking into the g.07 LOS drift near scientific station No. 1 on 20 December. An exposure rate of 50-100 mR/h was detected in the test chamber area. The exposure rate at the test chamber door was 500 mR/h.

On 26 December test chamber No. 1 was entered for documentary photographs. The exposure rate in the test chamber was 2.5 R/h. Photography in test chamber No. 1 by various agencies continued on 27 December with experiment recoveries from this station beginning on this same date. All major experiment recoveries from test chamber No. 1 were completed by 4 January.

Photography and recovery work in test chamber No. 2 began on 4 January; the maximum exposure rate was 15 R/h, with a general exposure rate of 5-7 R/h. No toxic gases or explosive mixtures were detected in the test chamber. Recovery operations from the LOS pipe were completed and experiments had been packaged for shipment by 15 January.

At the close of reentry activities, a concrete plug was placed in the reentry drift to close off the g.07 reentry/recovery drifts.

3.4.4 Postevent Drilling

LASL personnel began postevent drilling operations at 1537 hours on 12 September 1967. The drill rig was set up and made ready earlier in the day; however, tunnel reentry activities delayed the start of drilling. Drilling began and continued until 0800 hours on 13 September when core sampling operations began. Core sampling was completed at 1130 hours. Twenty samples were taken with a maximum intensity of 11 R/h at contact with a single core sample.

The drill hole was sealed with a ball valve and blind flange to facilitate subsequent use of the hole by DOD/SC; therefore, capping integrity was not determined for this drillback. Telemetry surveillance was maintained for approximately 18 hours after closing in the hole, during which time no gross leaks were detected.

Operations were completed at 1300 hours on 14 September. Releases of radioactive effluent during this drillback were below the detection limit of the telemetry array. The maximum gamma reading not associated with a core sample was 160 mR/h at contact with a drilling tool at 0110 hours on 14 September.

A survey of the cellar showed a maximum spot contamination of 0.6 mR/h. No alpha radiation was detected at any time during the drillback operation.

3.4.5 Industrial Safety

Checks were made on each shift for radiation levels, toxic gases, and explosive mixtures. These measurements were then recorded in the monitors' log book. Maximum industrial hygiene readings for the DOOR MIST event were:

1. 14,000 ppm CO_2 on 19 September 1967 at the junction of the GZ personnel and scientific drifts.

2. 40 ppm $NO+NO_2$ on 1 November 1967 in the reentry drift.

3. 100 percent of the LEL on 22 November 1967 during a routine survey of the work area.

4. 25,000 ppm CO on 27 November 1967 during a routine work area survey of the U12e.04-g.07 work area.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes, including specific codes for mining, tunneling, and drilling were established by REECo and emphasized during all operations.

The portal construction area and the tunnel were hard hat and foot protection areas (safety shoes, safety boots, miners boots or toe guards). Each participating agency provided its own safety equipment.

3.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 0931 hours on 31 August 1967 and ended at 1500 hours on 11 November 1967. The maximum gamma exposure rate measured was greater than 1,000 R/h at underground stations 27 through 33 and 36 at various times on 31 August 1967.

The initial surface radiation survey teams entered the area at 1036 hours and completed the survey at 1117 hours on 31 August 1967. The maximum gamma exposure rate obtained was 200 mR/h at the Rainier Mesa trailer park security fence at 1117 hours. No alpha radiation was detected.

LASL began postevent drilling operations at 1537 hours on 12 September 1967, and completed the effort at 1300 hours on 14 September 1967. The maximum core sample contact intensity was 11 R/h, and the maximum gamma reading obtained, not associated with a core sample, was 160 mR/h at contact with a drilling tool at 0110 hours on 14 September 1967. No alpha radiation was detected.

Postevent mining began at 1530 hours on 28 September 1967 and all major experiment recoveries were completed by 15 January 1968. The maximum gamma personnel exposure rate measured was 15.0 R/h at test chamber No. 2 on 5 January 1968. No alpha radiation was detected.

Personnel exposures received during individual entries to DOOR MIST radex areas from 31 August 1967 to 31 January 1968 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)	Average Exposure (mR)
All Participants	4,215	1,625	82
DOD Participants	468	1,185	155

CHAPTER 4

DORSAL FIN EVENT

4.1 EVENT SUMMARY

DORSAL FIN was an underground DOD weapons effects test conducted at tunnel site U12e.10 (Figure 4.1) on 29 February 1968 at 0908 hours Pacific Standard Time (PST). The device, which had a yield less than 20 kt, was emplaced at a vertical depth of 1,345 feet. The test objective was to obtain information on the response of material and equipment to a nuclear detonation environment. Government agencies and contractors conducted 15 projects to obtain desired weapons effects information. Containment of the DORSAL FIN event was complete. No radioactive effluent was detected onsite or offsite from this event.

4.2 PREEVENT ACTIVITIES

4.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all DORSAL FIN 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. Sandia Corporation was responsible for timing and firing systems, stemming design, and for installation of necessary measuring devices and equipment to indicate postevent tunnel condition. EG&G personnel were responsible for timing and firing mechanisms for the device which was provided by LASL.

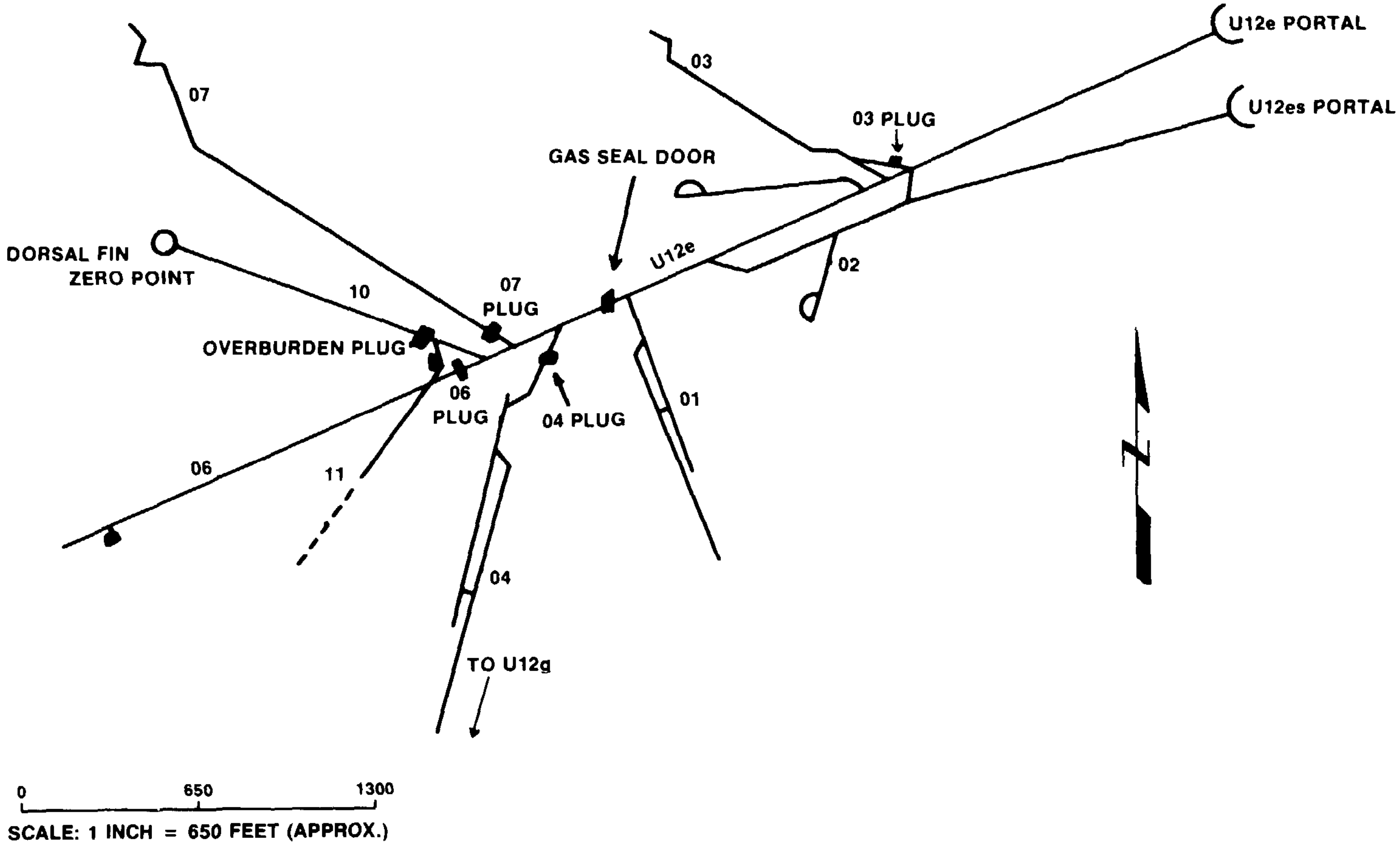

Figure 4.1 DORSAL FIN event - tunnel layout.

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

The LASL Test Group Director was responsible for the area within a 6,000-foot radius of the zero point. This responsibility was in effect from the time the device was moved to the zero point area until the device was detonated. At that time, the Test Manager relieved the LASL Test Group Director of responsibility pursuant to provisions of NTSO guidance, and delegated responsibility to the DOD Test Group Director.

4.2.2 Planning and Preparations

The "DORSAL FIN Reentry Plan" described preevent preparations and postevent procedures used to conduct a safe and economical reentry within the desired time frame.

A. Radiological Safety Support

Detailed radiological safety reentry plans were provided to participating agencies prior to the test event. Test area maps with appropriate reference points were prepared. Reference markers and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs." Radsafe personnel were briefed regarding reentry, sample recovery, manned stations, and security station requirements.

Radsafe monitors were stationed at all WSI security roadblocks, manned stations, and work areas located within the controlled area. Personnel at these locations were provided with appropriate anticontamination clothing and equipment. Available materials included coveralls, head covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, shoe covers, plastic bags, and masking tape.

Radsafe provided monitoring teams and supervisory personnel for surface radiation surveys, helicopter surveys, and tunnel reentry parties. These personnel were stationed at the DOD Test Group Director's FCP to perform initial and subsequent surveys as required; provide emergency rescue and support as directed; provide and issue anticontamination equipment, portable instruments, and dosimetric devices; perform personnel, equipment, and vehicle decontamination; and operate a sample return station.

A mobile issue facility for anticontamination clothing, respiratory protection equipment, instruments, and dosimetric devices was positioned, prior to the event, at the security barricade near the FCP. When authorized by the Test Group Director, this facility was repositioned to a convenient location near the tunnel portal. A personnel and vehicle decontamination facility was established adjacent to the mobile issue facility for use if needed.

B. Telemetry and Air Sampling Support

Forty-five RAMS units were in operation; 26 on the surface and 19 inside the tunnel (Table 4.1). Prior to DORSAL FIN, the original U12e portal and main drift had been abandoned, except for the vent lines, when a second entrance to U12e was mined (U12es), and this portal and drift were used for DORSAL FIN. However, the U12e por-

Table 4.1. DORSAL FIN RAMS unit locations.

Station	Location
	ABOVEGROUND
3	225 feet at 10° azimuth from e portal
4	300 feet at 45° 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	195 feet at 303° azimuth from e portal
9	200 feet at 22.5° 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	Filter
15	Blower Stack
16	Blower Stack
17	2,250 feet at 63° 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 337° azimuth from Station No. 6
22	200 feet at 180° azimuth from U12e.10 cable hole No. 2
23	220 feet at 90° azimuth from U12e.10 cable hole No. 2
24	0 feet from U12e.10 cable hole No. 2
25	225 feet at 270° azimuth from U12e.10 cable hole No. 2
26	250 feet at 0° azimuth from U12e.10 cable hole No. 2

Table 4.1. DORSAL FIN RAMS unit locations (concluded).

Station	Location
	ABOVEGROUND (Continued)
27	500 feet from ul2e.10 cable hole at 180° azimuth
28	500 feet from ul2e.10 cable hole at 60° azimuth
29	500 feet from ul2e.10 cable hole at 300° azimuth
	UNDERGROUND
33	1,000 feet from U12e.10 drift
34	875 feet from U12e.10 drift
35	580 feet from U12e.10 drift
35a	580 feet (buried 24 inches) from U12e.10 drift
36	430 feet from U12e.10 drift
36a	430 feet (buried 24 inches) from U12e.10 drift
37	370 feet from U12e.10 drift
37a	370 feet (buried 24 inches) from U12e.10 drift
38	500 feet from U12e.06 drift
39	290 feet from U12e.06 drift
41	100 feet from U12e.04 drift
42	3,475 feet from U12e main drift
43	3,425 feet from U12e main drift
44	1,090 feet (buried 24 inches) from U12e.10 drift
45	2,886 feet from U12e main drift
46	1,850 feet from U12e bypass drift
48	At es access drift
49	At e access drift
50	3,900 feet from U12e main drift

tal was used as a point from which to measure distances to RAMS unit locations as well as the U12es portal. All detectors in the tunnel were housed in explosion-proof steel boxes and were encased in foam jackets to provide shock mitigation. These units each used a pair of signal wires to conduct signals to the reentry safety trailer located at the FCP. Surface locations were chosen with a consideration for weather conditions required at zero time and for terrain features. The instrumentation was to detect airborne radioactive effluent in case of venting for purposes of reentry safety and documentation of compliance with the Test Ban Treaty.

Air sampling units were positioned at six surface locations (two at each portal and two in the trailer park). Air sampling locations were selected by an actual onsite survey with consideration given to surface features and practicality of installation. The units were started and set in continuous sampling mode approximately three hours prior to scheduled device detonation by Radsafe manned station personnel.

PHS air samplers were operating at 105 routine stations in the offsite area, and 24-hour sample filters were collected daily. Ten PHS personnel were on duty for offsite surveillance activities during and after this event.

C. Security Coverage

Muster stations were established at the Rainier Mesa check point just west of Area 12 camp and on the Stockade Wash Road east of the Pahute Mesa Road. WSI personnel performed sweeps of the controlled area and issued muster badges to all personnel. Control of the area was maintained by using roadblocks, access permits, and a "Schedule of Events."

D. Air Support

A UH-1F helicopter was flown by a USAF pilot with three military crewmen to perform still photography coverage of the event for the APS. A separate DOD photo mission was flown by a USAF pilot and one crewman in a UH-1F helicopter. Both aircraft had Radsafe monitors on board. A U-6A aircraft was used by security personnel to perform aerial security surveys and sweeps. PHS had a USAF U-3A aircraft and two Turbo-Beech aircraft available for cloud tracking and sampling. The U-3A was flown by a USAF pilot with two PHS personnel as crew. Both Turbo-Beech aircraft were manned by civilian pilots and crews. In addition, the EG&G/NATS aircraft was on standby at McCarran Airport in Las Vegas in case it was needed for cloud tracking.

4.2.3 Late Preevent Activities

A readiness briefing was held at 1600 hours on 28 February.

The first security sweep of the controlled area began at 2025 hours on 28 February. At that time, all experimenter personnel who did not have permission to remain were mustered from the closed area. Gates at E and G tunnels were locked and secured. This security sweep was completed at 2340 hours.

4.3 EVENT-DAY ACTIVITIES

WSI personnel began the second security sweep at 0108 hours on 29 February (D-day). This sweep was completed at 0305 hours. At 0430 hours, the WSI muster station was moved from the intersection of Pahute Mesa and Stockade Wash Roads to the intersection of Pahute Mesa Road and Road 16-02. Personnel representing DASA, REECo, EG&G, LASL, SRI, and WSI were inside the closed area performing final button up activities until 0545 hours. By 0655, the area was clear except for the arming party and the zero point security guards. At that time, permission to arm the device was granted. The arming party performed their mission and exited the area at 0745 hours. A final aerial security sweep was performed, after which the photographic aircraft took their positions and were in place by 0855 hours for scheduled event execution at 0900 hours. However, a technical hold was called at H-2 seconds. The technical problem was quickly solved and the countdown resumed.

DORSAL FIN zero time was 0908 hours PST on 29 February 1968.

Telemetry measurements were recorded from 0909 hours on 29 February through 1600 hours on 8 March 1968. With the exception of detectors identified as underground RAMS Stations 35, 35a, 36, and 36a, which measured some activation products, all radiation detectors both in the tunnel and aboveground indicated preevent background readings after detonation.

RAMS Unit	H+1 Min.	H+250 Min.
35	260 R/h	1 R/h
35a	5 R/h	16 mR/h
36	8 R/h	40 mR/h
36a	300 mR/h	1.5 mR/h

The presence of background readings on the bulk of the aboveground RAMS units indicated that containment within the tunnel had been good.

4.3.1 Radiation Surveys and Surface Reentry

Initial surface radiation survey teams, dressed in anticontamination clothing and provided with respiratory equipment, entered the closed area at 1045 hours and completed the surface initial survey at 1138 hours on D-day.

There were four Radsafe reentry teams, each consisting of two Radsafe monitors. Teams No. 1 and No. 2 were stationed at the FCP. When released by the Test Group Director, they proceeded to the E tunnel portal area. Team No. 1 surveyed the new portal (es) while team No. 2 surveyed the trailers and cable runs, beginning with the first trailer in the old portal (e) area.

Teams No. 3 and 4 were stationed at the Rainier Mesa security check point. When released by the Test Group Director, they traveled to the Rainier Mesa trailer park where team No. 3 surveyed the U12e tunnel vent holes. Team No. 4 surveyed the trailer park and cable runs. Both teams then stood by at the cable runs until all trailer recoveries were completed and downhole cables were disconnected.

All surface initial survey radiation measurements indicated background levels.

4.3.2 Experiment Recovery Activities

After the initial portal and Rainier Mesa radiation surveys were completed, the DOD Test Group Director released parties from LASL, SRI, LMSC, DOD, EG&G, General Atomic (GA), and SC to recover data and instruments from Rainier Mesa trailer park. Shortly thereafter, DOD Test Group personnel led DOD and SC data recovery teams to the portal area to reenter SC trailers which were located there. The gas sampling system was operated from these trailers. No radiation problems were encountered.

4.4 POSTEVENT ACTIVITIES

4.4.1 Tunnel Reentry and Experiment Recovery

Tunnel ventilation by exhaust was initiated immediately following the detonation. This diluted or removed any existing toxic or radioactive aerosols via a filtering system and the exhausting vent lines. Ventilation effluent was monitored for radioactivity and toxic gases to evaluate the adequacy of implemented safety controls prior to tunnel entry by the initial reentry party.

Each member of the initial reentry teams was provided with sets of required anticontamination clothing; two self-reading pocket dosimeters (0-200 mR, 0-5 R); one two-hour McCaa breathing device; a Bureau of Mines-approved, hat-mounted miner's light with battery pack; and an MSA-approved explosive-proof flashlight. Subsequent reentry and recovery parties were equipped with full-face masks beyond the overburden plug.

A. <u>D+1 (1 March 1968)</u>

When cleared by the DOD Test Group Director, and when all surface recoveries were complete, tunnel reentry teams No. 1 and 2 began initial tunnel reentry. Team members were dressed as discussed above. This occurred on 1 March 1968 beginning at 1015 hours. The reentry teams proceeded from the portal to the gas seal door surveying for toxic gases, explosive mixtures, and radioactivity. The maximum radiation reading was 1.5 mR/h at the junction of the old main drift (e) and bypass main drift (es) at 1,700 feet. All other readings to this point were less than 0.5 mR/h.

Opening the manway door in the gas seal door at 1125 hours revealed approximately two feet of water on the zero point side. Pumps were turned on to remove the water. At 1135 hours, reentry team No. 3 (dressed in the same manner as the previous teams except for McCaa breathing devices) entered the tunnel to open the large gas seal door (only the manway door was previously opened) and establish railroad tracks through the door. Although full-face masks were not required to be worn at the gas seal door, any person entering the tunnel was required to have a mask in his possession. The gas seal door was opened and tracks reinstalled, and team No. 3 exited the tunnel at 1400 hours.

Between 1430 and 1540 hours, team No. 1 (appropriately dressed-out) performed a radiation survey from the gas seal door to the overburden plug. From 2,900 feet in the main drift to the 07 junction, gamma exposure rate readings of 0.5 to 0.7 mR/h were measured. No explosive mixtures or toxic gases were encountered. Vent lines through the overburden plug were opened in preparation for ventilating behind the blast door. At 2000 hours, the overburden plug was opened and survey measurements showed 10,000 ppm CO, less than 0.5 mR/h gamma exposure rate, and 15 percent LEL of explosive mixtures.

Miners removed sand from the vent lines and began hooking them up in order to begin ventilation in the early morning hours of 2 March.

B. D+2 (2 March 1968)

By 0800 hours, tunnel ventilation had been established to the overburden plug. Reentry team No. 1 entered the tunnel and performed a walkthrough from the overburden plug to the LOS pipe drift. Water was still being pumped from the tunnel at this time. Other than the water problem, the drift was found to be clear. Maximum radiation readings were 45 mrad/h beta plus gamma, and 40 mR/h gamma. No explosive mixtures or toxic gases were encountered.

After several hours of pumping water from the tunnel, a team entered the LOS drift for an initial survey at 1425 hours. Scientific station No. 2 was reached and opened at 1515 hours. A maximum gamma reading of 150 mR/h was detected, but no explosive mixtures or toxic gases. The team next opened the door to scientific station No. 1 at 1530 hours. No explosive mixtures were detected; however, 100 ppm CO and 125 mR/h gamma were measured. The reentry team exited the tunnel at 1600 hours. Shortly after their exit, experiment recovery operations were authorized.

Experiment recovery parties from EG&G, Naval Research Laboratory (NRL), Nuclear Defense Laboratory (NDL), LASL, and LRL entered the tunnel at 1630 hours. All personnel were appropriately dressed for work in this radex area. Work continued for approximately an hour before parties began exiting the tunnel. Alpha contamination was detected in the LOS pipe and up to 25,000 cpm was detected on anticontamination clothing. All personnel were decontaminated as needed and urine samples were collected.

C. <u>D+3 (3 March 1968)</u>

Miners and Radsafe personnel were the first to enter the 010 drift at 0800 hours on this date. Radsafe personnel made routine checks and detected alpha contamination of 3,000 cpm. They immediately left the tunnel to inform the supervisor and tunnel superintendent, and to redress in double anticontamination clothing. Before they reentered, they were advised by the tunnel superintendent that once the Radsafe station was installed underground and all drainage pumps were installed on the zero point side of the overburden plug, all personnel would depart the tunnel for the remainder of the day. Upon reentering the tunnel, a complete survey of the work area disclosed that the alpha contamination problem persisted. The Radsafe station was installed on the portal side of the overburden plug. Surveys detected alpha levels ranging from 3,000 cpm to 100,000 cpm. A Radsafe hot line was set up outside the overburden plug for control. Urine samples were collected from personnel exiting the tunnel. By 1300 hours, all personnel were out of the area with the exception of hourly security checks by Wackenhut Services, Inc. (WSI) personnel.

D. D+4 (4 March 1968)

No recovery operations were performed until 1605 hours on 4 March. Photographers were in the tunnel earlier in the day, but it was not until SC personnel reentered scientific station No. 1 that experiment recovery operations resumed. Operations were complete for the night at 2200 hours. All personnel were monitored by Radsafe after removal of anticontamination clothing and no alpha activity was detected.

E. D+5 (5 March 1968)

Walkout of the LOS pipe was completed at 1300 hours. The LOS pipe was partially collapsed but DOD and LRL personnel completed their recovery operations. Experiment recovery operations continued to be conducted by SC, LRL, and LMSC personnel at scientific stations No. 1 and 2.

F. Extended Recovery Activities

Routine scientific recoveries were made by personnel representing LRL, LMSC, SC, AFWL, AVCO Corporation (AVCO), LASL, GA, SRI, EG&G, and DOD during the period from 5 March through 11 April 1968. Alpha contamination was confined to the area between the overburden plug and scientific station No. 1. Urine samples taken from reentry personnel showed no detectable alpha emitters. No other radiological problems were encountered.

4.4.2 Postevent Drilling

Postevent drilling on PS-1V began at 1325 hours on 6 March 1968. Drilling continued until a total depth of 1,504 feet was reached at 0205 hours on 7 March 1968. Then the decision was made to begin core sampling at 0300 hours. The lab trailer continuous air monitor detected increased radioactivity levels beginning at 0312 hours, reaching a maximum of 10,000 cpm of gamma activity at 0330 hours, and steadily decreasing thereafter. It was discovered that a portion of a core sample had fallen into the cellar causing radioactivity to be introduced into the recirculation blower system. A cellar survey at 0340 hours indicated a maximum reading of 0.6 mrad/h beta plus gamma, and an air sample taken at the same time indicated no gaseous contamination in the cellar. The drill rig was washed down at 0830 hours, and the platform radiation readings decreased. Coring operations were completed at 1230 hours on 7 March. A total of 19 core samples were taken with a maximum contact radiation reading of 5 R/h for a single core sample. The containment plug was closed at 1605 hours and the blind flange set at 1630 hours. Rig teardown began at 1730 hours on 7 March and the rig was removed by 2030 hours.

4.4.3 Industrial Safety

Each participant in tunnel reentry operations was certified by the Bureau of Mines as having satisfactorily completed training in the use of the 2-hour McCaa breathing apparatus, and had been instructed in mine rescue procedures.

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 were established by REECo and were emphasized during all operations.

4.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 0909 hours on 29 February 1968, and ended at 1600 hours on 8 March 1968. The maximum gamma exposure rate measured was 260 R/h at 5+80 feet into the U12e.10 drift at 0909 hours on 29 February 1968.

The tunnel reentry survey teams entered the area at 1015 hours and completed the survey to the overburden plug at 1540 hours on 1 March 1968. The maximum gamma exposure rate obtained during the initial survey was 1.5 mR/h at construction station 17+00 in the main drift (es). No alpha radiation was detected.

Postevent recovery operations began at 1145 hours on 1 March 1968 and were completed on 11 April 1968. The maximum gamma exposure rate measured was 150 mR/h both outside and inside test chamber No. 2 at 1454 hours on 2 March 1968. The maximum alpha radiation measurement obtained was 100,000 cpm at contact with the portal side of test chamber No. 1 at 0930 hours on 3 March 1968. Evaluation of urine sample results indicated that no significant internal deposition had occurred.

Postevent drilling began at 1325 hours on 6 March 1968, and the containment plug was set at 1605 hours on 7 March. The maximum gamma activity rate obtained during drillback operations was more than 5 R/h at contact with a core sample on 7 March. The maximum alpha radiation measurement obtained was 10,000 cpm on the platform at 0330 hours on 7 March 1968.

Personnel exposures received during individual entries to DORSAL FIN radex areas from 29 February 1968 to 9 May 1968 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)	Average Exposure (mR)
All Participants	1,266	120	4
DOD Participants	240	40	10

CHAPTER 5

MILK SHAKE EVENT

5.1 EVENT SUMMARY

The MILK SHAKE event was conducted on 25 March 1968 at 1044 hours PST. LRL supplied the device, which had a yield less than 20 kt. Device emplacement was at shaft site U5k in a 66-inch diameter cased hole drilled to a depth of 867 feet (Figure 5.1). A vertical LOS pipe which had a 37-inch opening at the surface was used. Seventeen projects were fielded by government agencies and contractors in support of the test objective, which was to determine response of test equipment and samples to a nuclear detonation environment.

A subsidence crater formed 21 minutes after detonation. Due to the failure of gas seals in the downhole cables, a slight release of radioactive gases occurred. Minor levels of radioactive effluent were detected onsite only.

5.2 PREEVENT ACTIVITIES

5.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all MILK SHAKE event activities in Area 5, 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. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

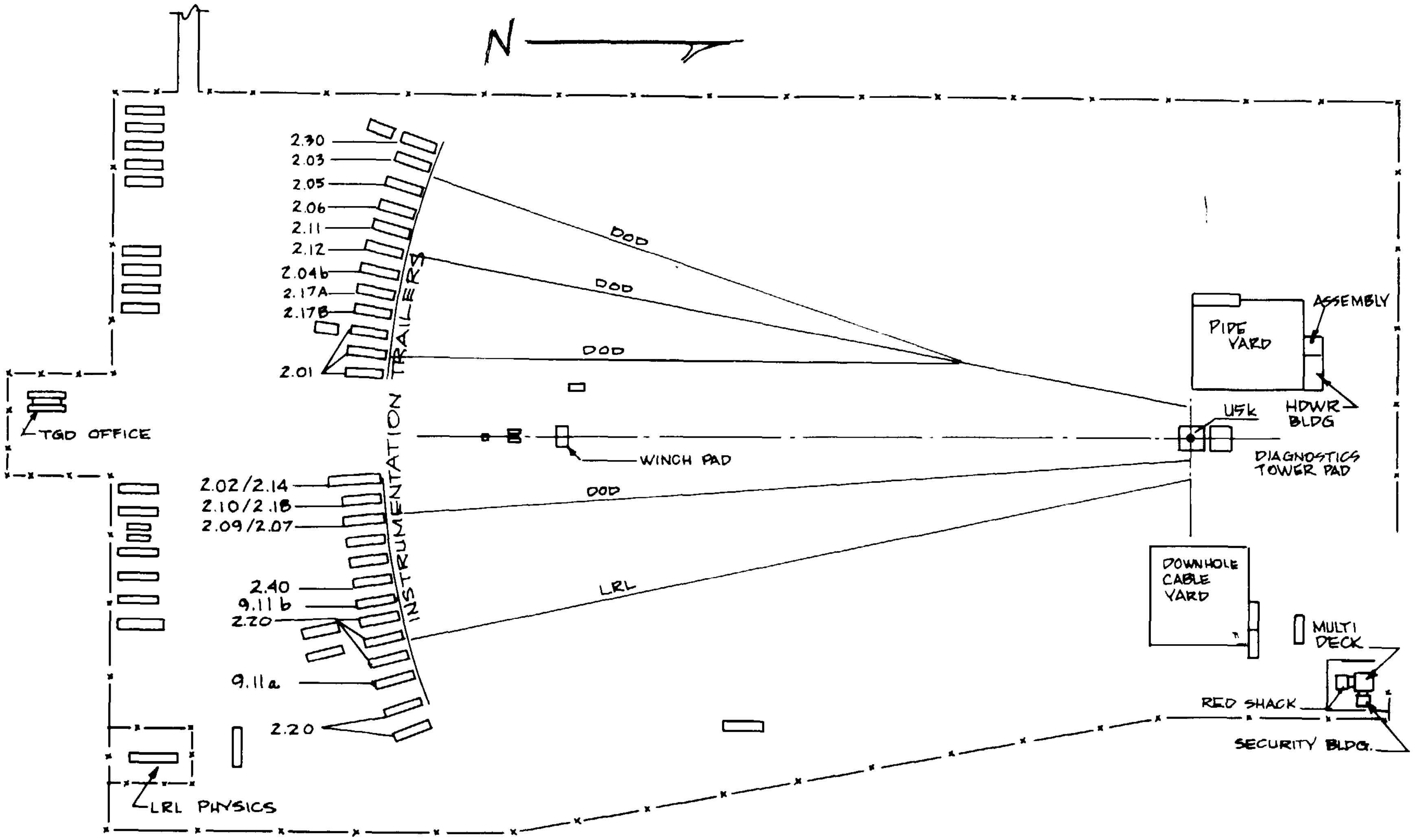

Figure 5.1 MILK SHAKE event - U5k site plan.

Project agencies were responsible for designing, preparing, and installing or delivering their experiments 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.

5.2.2 Planning and Preparations

A. Radiological Safety Support

Detailed radiological safety reentry plans were provided to participating agencies prior to the test event. Reference markers and air sampling equipment were positioned in the test area. "Dry runs" were performed to establish reentry routes into the test area. Radsafe personnel were briefed regarding surface reentry, manned stations, and security station requirements.

All remote area monitoring stations and air sampling units were installed according to DOD and LRL specifications prior to D-5 days.

All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance.

Radsafe provided monitoring teams and supervisory personnel for initial surface radiation surveys, aerial surveys by helicopter, and reentry parties as needed. In addition, Radsafe personnel were standing by at the DOD Test Director's FCP prior to scheduled 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 coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

B. Telemetry and Air Sampling Support

Seventeen remote telemetry radiation monitoring stations provided event coverage as shown in Table 5.1.

Eighteen air sampling units with detector recorders were in operation at zero time. These units were positioned at 20° intervals on a 2,000-foot arc beginning at 20° azimuth. Samplers were started and set on continuous sampling mode by manned station teams five hours before scheduled device detonation.

PHS air samplers were operating at 108 routine stations at offsite locations.

C. Security Coverage

All personnel entering or exiting the controlled area were required to stop at the muster or control stations for issuance or return of their muster or stay-in badges. All personnel were required to have proper security clearances for the area. Control of the area was maintained by using roadblocks, access authorizations, and a "Schedule of Events." Parties could enter the controlled area only if they were listed on the "Test Manager's Schedule of Events," or with permission of the Test Group Director. WSI security guards were responsible for activating roadblocks to direct traffic flow.

Table 5.1. MILK SHAKE event RAMS unit locations.

Station	Location (from SGZ)
1	SGZ
2	350 feet at 180° azimuth
3	750 feet at 0° azimuth
4	750 feet at 45° azimuth
5	750 feet at 90° azimuth
6	750 feet at 159° azimuth
7	750 feet at 184° azimuth
8	750 feet at 202° azimuth
9	750 feet at 270° azimuth
10	750 feet at 315° azimuth
11	2,500 feet at 0° azimuth
12	2,500 feet at 45° azimuth
13	2,500 feet at 90° azimuth
14	2,500 feet at 135° azimuth
15	2,500 feet at 180° azimuth
16	2,500 feet at 225° azimuth
17	2,500 feet at 270° azimuth
18	2,500 feet at 315° azimuth

D. Air Support

A UH-1F helicopter was flown by a USAF pilot with three military crewmen and a Radsafe monitor on board to perform still photography coverage of the event. A USAF U-6A aircraft was used by security personnel to perform aerial surveys. PHS had a USAF U-3A aircraft and two Turbo-Beech aircraft on standby status. The U-3A was flown by a USAF pilot with two PHS crew members.

5.2.3 Late Preevent Activities

On D-6 days, a practice reentry was staged from the primary MILK SHAKE recovery point. The final timing and firing dry run was performed on D-2.

On D-1, final button up activities were performed by personnel from LMSC; Massachusetts Institute of Technology (MIT); Space and Missile Systems Organization (SAMSO); AVCO; GA; Boeing Aircraft Co. (BAC); Harry Diamond Laboratories (HDL); Naval Ordnance Laboratory (NOL); NRL; SRI; Moleculon Consultants, Inc. (Moleculon); LRL; LASL; and SC. Initial preevent security sweeps were begun and muster and control stations were established.

5.3 EVENT-DAY AND CONTINUING ACTIVITIES

Readiness briefings were conducted during the pre-dawn hours on D-day.

MILK SHAKE zero time was 1044 hours PST on 25 March 1968.

Telemetry measurements began at 1045 hours on 25 March. An effluent release, which apparently came from a downhole cable, began at 1051 and lasted until 1145 hours. All radiation levels had decreased to background by 0800 hours on 26 March. The maximum gamma exposure rate measured was 4.5 R/h at SGZ on 25 March at 1045 hours. Telemetry coverage for MILK SHAKE was terminated on 27 March 1968 at 1600 hours.

Cavity collapse occurred at 1105 hours on D-day.

5.3.1 Cloud Tracking and Sampling

Two PHS monitors performed initial monitoring in a USAF U-3A aircraft. One of the PHS Turbo-Beech aircraft (Vegas 8) was used to perform additional aerial monitoring and cloud sampling. The cloud was sampled as it drifted northeast from SGZ.

A. U-3A Tracking Mission

A background level exposure rate was measured on the first pass over SGZ at 3,850 feet MSL. The first reading above background was 0.18 mR/h over SGZ at 1051 hours. The remaining measurements recorded on this flight are summarized in Table 5.2. A final axial pass from north of Papoose Lake, starting at approximately 15° and 20 miles out and flying toward SGZ, detected only a trace of activity over Papoose Lake at 1230 hours. The aircraft completed its mission and returned to ISAFAF at 1300 hours.

B. Vegas 8 Mission

Vegas 8 first entered the cloud at 1105 hours on D-day. At 1107 hours, the cloud's leading edge was located 3.4 miles from SGZ on a 15° azimuth. A spiral descent was made through the release plume two miles from SGZ at 1115 hours. Vegas 8 established a sampling path ahead of the cloud at 5000 feet MSL 6.5 miles from SGZ and

Table 5.2. MILK SHAKE event - U-3A cloud tracking summary, 25 March 1968.

Time (Hours) (PST)	Altitude (ft, MSL)	Azimuth from SGZ (degrees)	Distance from SGZ (miles)	Exposure Rate (mR/h)	Remarks
1051	3850	0	0	0.18	
1058	3850	20	0.2	9.0	
1100	4000	10	1.0	1.0	
1117	4000	10	5.0	0.6	
1122	4000	15	7.0	0.6	
1123	4000	15-20	10.0		Leading Edge
1151	4000	20	12.0		Leading Edge
1159	4000	20	13.0	0.13	Over Papoose Lake
1215	4000	20	14.0	Bkg*	
1232	6500	15	15.0	Trace	

*Background radiation measurement.

normal to the direction of cloud movement. Sampling was performed from 1119 until 1208 hours, at which time the majority of the radioactive effluent appeared to have passed the sampling line. An axial pass beginning 6.5 miles from SGZ, along the 15° azimuth, showed continuous very small amounts of activity.

Sequential samples were collected on the spiral descent and four cross passes were made. Because the sample volumes were small and half-lives short for the particulate activity, there was insufficient activity for meaningful analysis.

The release of activity from the MILK SHAKE event consisted primarily of noble gases. At the time of sampling, the major radionuclide detected was cesium-138. The low concentration and short half-lives of the radionuclides involved resulted in the conclusion that no detectable concentrations were released offsite.

5.3.2 Test Area Radiation Surveys and Reentry Activities

Initial radiation survey teams No. 1 and 2 were officially released from the FCP at 1117 hours. They entered the area at 1118 hours and completed their surveys at 1225 hours (Table 5.3). The maximum gamma exposure rate obtained was 15.0 R/h at contact with the cables to the EG&G Trailer 9.11a. No alpha radiation was detected.

5.3.3 Experiment Recovery Activities

Experiment recovery operations began on D-day at 1215 hours and continued through D+3 days. Only trailer park recoveries were performed on D-day; however, trailer park and tower recoveries were conducted through D+3 days. Representatives from DASA, AFWL,

Table 5.3. MILK SHAKE event - initial radiation survey data, 25 March 1968.

Time (Hours)	Location (from SGZ)	Gamma Exposure Rate (mR/h)
1118	Stake 5Y13 (2.7 miles SW)	0.07
1119	Stake 5Y15 (2.2 miles SW)	0.08
1120	Stake 5Y17 (1.7 miles SW)	0.07
1120	Stake 5Y19 (1.3 miles (SW)	0.07
1121	Watsonville (Area 5 Compound)	0.07
1123	0.1 mile west of trailer fence	0.3
1124	Entrance to trailer park	1.0
1126	Center of trailer park	9.0
1127	East end of trailer park	30.0
1133	Cables to trailer No. 9.11a	10,000.0*
1138	Door to trailer No. 9.11a	2,000.0
1139	Door to trailer No. 102	200.0
1140	Door to trailer No. 40003	1.0
1155	Cables to trailer No. 9.11a	15,000.0*
1213	Trailer No. 9.11b	7.0*
1225	Inside trailer No. 9.11a	1,500.0*

*Contact radiation reading

Moleculon, AVCO, EG&G, LRL, BAC, GA, HDL, SC, Army Pictorial Center (APC), LMSC, NRL, LASL, MIT, GE, and NDL participated in experiment recovery operations.

Experiment recovery teams arrived at the tower at 0800 hours on 26 March. When the main steps were ready to be placed on the tower, all electricity to the tower was shut off. Contractor personnel used a hydrocrane to position the tower steps. An SC/REECo safety group then entered the tower exposure room to check for any potential safety problems. Following completion of the tower safety inspection, specific project personnel were allowed to enter the tower and remove critical equipment and take measurements. These personnel were required to wear full-face masks in addition to full anticontamination clothing at all times. The safety team remained at the tower until all project agency personnel had departed.

5.4 POSTEVENT ACTIVITIES

5.4.1 Tower Experiment Recovery Activities

Trailer park recoveries which were begun on D-day continued. In addition, project agencies were allotted time after D-day to recover experiment cassettes from the tower. All recovery operations were performed without incident. After experiment recovery operations were completed, the tower was partially disassembled and transported to the Area 5 radioactive waste storage facility.

5.4.2 Postevent Drilling

No surface drillback operations were conducted for this event.

5.4.3 Industrial Safety

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 a project was required to be knowledgeable regarding applicable procedures for their project.

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

5.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1045 hours on 25 March 1968 and ended at 1600 hours on 27 March 1968. The maximum gamma exposure rate measured by telemetry was 4.5 R/h at SGZ on 25 March at 1045 hours.

The initial radiation survey was conducted between 1118 hours and 1225 hours on 25 March 1968. The maximum gamma exposure reading obtained was 15.0 R/h at contact with the cables to the EG&G Trailer 9.11a. No alpha radiation was detected.

Personnel exposures received during individual entries to MILK SHAKE radex areas from 25 March 1968 to 8 August 1968 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)	Average Exposure (mR)
All Participants	491	545	12
DOD Participants	212	140	13

No radioactivity above normal 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. No fresh fission products were detected in any environmental sample collected offsite throughout this period, and no prefilter air samples contained levels of gross beta activity above normal background.

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

CHAPTER 6

DIANA MOON EVENT

6.1 EVENT SUMMARY

DIANA MOON was a DOD-sponsored underground test detonated at 0930 hours PDT on 27 August 1968 with a yield less than 20 kt. Device emplacement depth was 794 feet in a 66-inch diameter cased hole (Ulle) with a 48 1/2-inch diameter LOS pipe to the surface. Experiments were arranged in a bell jar/instrument spool resting on a recoverable sled (Figure 6.1). The objective of this test was to obtain weapons effects information related to the response of materials and equipment to the environment produced by a nuclear detonation. Government agencies and contractors conducted eight projects to obtain the desired information.

A subsidence crater formed six minutes after detonation. Minor seepage of radioactive effluent was detected in the SGZ area from H+3 minutes (0933 hours) to H+17 minutes (0947 hours), and again from H+5 hours (1430 hours) to H+13 hours (2230 hours). No radioactive effluent was detected offsite.

6.2 PREEVENT ACTIVITIES

6.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all DIANA MOON project activities in Area 11. 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. LASL fielded the device; therefore, the LASL Test Group

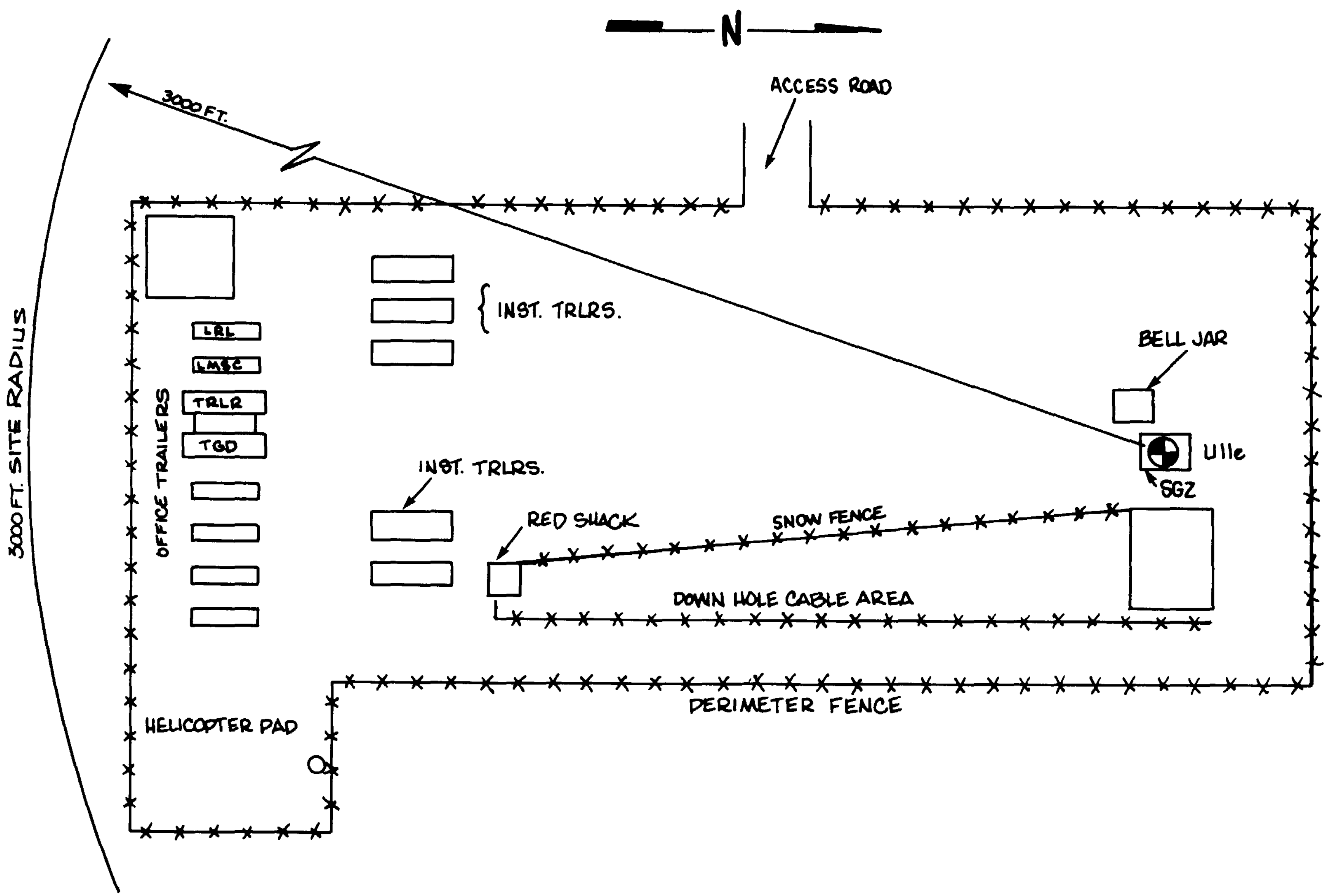

Figure 6.1 DIANA MOON event - Ulle site plan.

Director was responsible to the Test Manager for the area within a 2,000-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 Test Manager relieved the LASL Test Group Director of responsibility which was subsequently delegated to the DOD Test Group Director.

Sandia Corporation was responsible for reentry and recovery safety and LASL performed downhole recovery work.

6.2.2 Planning and Preparations

A. Radiological Safety Support

Procedures for radiation exposure and contamination control during this event were in accordance with the requests of responsible DOD and SC representatives. Participating agencies were provided with detailed radiological safety reentry plans prior to the test event. Monitors were briefed regarding test area surface reentry, manned stations, and security station requirements.

Radsafe provided reference markers, monitoring and equipment support, and air sampling and telemetry arrays which were positioned in the test area prior to D-5 days. Two reserve Radsafe monitoring teams were on standby for use by the Test Manager in emergency situations. All personnel at manned stations were provided with appropriate anticontamination clothing and equipment. Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

Monitoring teams and supervisory personnel were provided for initial surface radiation surveys, aerial surveys, and reentry parties as needed. Radsafe personnel were standing by at the FCP prior to detonation to:

- perform surveys and provide emergency support as directed;

- provide and issue anticontamination equipment and materials, portable instruments, and dosimeters;

- operate area control check stations; and

- perform personnel, equipment, and vehicle decontamination as required.

B. Telemetry and Air Sampling Support

Seventeen RAMS units provided coverage for the DIANA MOON event as shown in Table 6.1.

Twelve air sampling units with detector recorders were located at 30° intervals on a 1,000-foot arc from SGZ beginning at 0° azimuth. These units were operational at zero time.

PHS air samplers were operating at 126 routine stations at offsite locations, and 19 personnel were on duty in the field to perform surveillance activities.

C. Security Coverage

Muster and control stations were established on D-day. All personnel entering or exiting the controlled area were required to stop at the appropriate station to obtain or to return their muster or stay-in badges. All

Table 6.1. DIANA MOON event RAMS unit locations.

Station	Location (from SGZ)
1	SGZ
2	600 feet at 0° azimuth
3	600 feet at 45° azimuth
4	600 feet at 90° azimuth
5	600 feet at 135° azimuth
6	600 feet at 171° azimuth
7	600 feet at 190° azimuth
8	600 feet at 220° azimuth
9	600 feet at 290° azimuth
10	600 feet at 315° azimuth
11	766 feet at 176° azimuth
12	2,000 feet at 0° azimuth
13	2,000 feet at 60° azimuth
14	2,000 feet at 120° azimuth
15	2,000 feet at 180° azimuth
16	2,000 feet at 240° azimuth
17	2,000 feet at 270° azimuth

personnel were required to have proper clearances for the area. Control was maintained by using roadblocks, access authorizations, and a "Schedule of Events." Personnel could enter the controlled area only if they were listed on the "Test Manager's Schedule of Events," or had the permission of the DOD Test Group Director.

D. Air Support

Aircraft support for this event was as follows:

Type	Organization	Mission
UH-1F	LMAFS	Photography
*UH-1F	DOD	Photography
*UH-1F	USAF/Test Manager	Standby
U-6A	WSI	Security
U-3A	USAF/PHS	Cloud Tracking
Turbo Beech	PHS	Cloud Sampling**
Turbo Beech	PHS	Cloud Sampling
Martin 404	EG&G/NATS	Cloud Tracking**
Cessna 206	AAS	Postevent Survey

*Dual function
**On standby in Las Vegas

6.2.3 Late Preevent Activities

Final dry runs were conducted on 26 August 1968 without incident. Button up activities at the trailer park were performed by personnel representing SC, LRL, EG&G, SRI, LASL, and DOD. During this time a high wind blew an empty box into the SGZ pit complex, damaging a vacuum readout probe and permitting a small amount of air to rush into the pipe before it could be repaired. After appropriate repairs were made, the vacuum system was checked and it performed as designed. A final readiness briefing was requested for 0400 hours on D-day, with an earliest event readiness of 0630 hours. The first security sweep began at 1915 hours and was completed at 2015 hours on D-1; the second sweep was conducted between 2130 and 2205 hours.

6.3 EVENT-DAY AND CONTINUING ACTIVITIES

At the 0400 readiness briefing, the weather forecast remained essentially the same as on the previous day with winds predicted to be 5 to 10 knots from the south. Air sampling units were started and set on continuous sampling mode by manned station teams five hours before scheduled device detonation. Permission to arm the device was requested and obtained at 0553 hours. The device was armed and the arming party exited the closed area by 0637 hours. Readiness at 0637 was attained; however, the unfavorable winds persisted at the event location, although reduced to light and variable, until about 0900 hours. At that time, a steady southerly air flow was observable on the Test Manager's closed circuit television (event location flags were waving), and weather bureau monitoring stations confirmed the flow. All experiment and containment system monitors were functioning properly, so permission to initiate countdown was requested and received. The countdown began at 0915 hours and proceeded without holds or accelerations.

DIANA MOON was detonated at 0930 hours PDT on 27 August 1968.

Telemetry coverage began at 0931 hours and continued until 2300 hours on 25 September 1968. The maximum radiation reading was 80 R/h at 0931 hours as indicated by the RAMS unit on the bell jar. This reading was attributed to activation products which were expected as part of the experiment. Approximately 20 seconds after detonation the recovery sled winch system was remotely activated to move the sled away from SGZ. This operation was successful, and the winch system was remotely disabled from CP at about 0933 hours when the monitor system indicated the sled had completed its desired travel. RAMS unit No. 2 (located 600 feet due north from SGZ) indicated 120 mR/h at 0931 hours; however, this measurement steadily decreased as the bell jar was pulled to the south.

A subsidence crater formed at 0936 hours. It was 264 feet in diameter and had a maximum depth of 17 feet.

6.3.1 First Radioactive Effluent Release Situation

The first seepage of radioactive effluent from SGZ began at 0933 hours and continued until 0947 hours. Radiation readings at RAMS unit No. 12 reached a maximum of 35 mR/h at 0940 hours. Readings at this unit then steadily decreased to background by 0954 hours.

By 1000 hours, all RAMS units continued to indicate decreasing readings. Therefore, permission to initiate reentry and recovery operations was requested and obtained.

6.3.2 Surface Reentry and Recovery Operations

Initial surveys of the Ulle trailer park, perimeter fence, crater, pit, and gas seals were conducted between 0947 and 1100 hours on D-day (Table 6.2). During these surveys, Radsafe personnel set up barricades around the bell jar and sled. When this was completed, the Test Director authorized personnel representing SC, SRI, LASL, EG&G, LRL, and NRL to recover film and tapes from the trailer park.

Reentry parties were required to wear full anticontamination clothing but no respiratory protection equipment.

Table 6.2. DIANA MOON event - initial radiation survey of trailer park area*, 27 August 1968.

Time (Hours)	Location	Gamma Exposure Rate (mR/h)
0957	Stake 5Y20	0.04
0958	Junction 5 Road and 5B Road	0.04
1000	Entrance to Ulle trailer park	0.7**
1000	West perimeter fence	3.0
1003	North perimeter fence	9.0
1005	Trailer LRL 170	0.7**
1006	East perimeter fence	5.0
1008	Cable run	0.7**
1010	Bell jar - southwest	1,500.0**
1013	Bell jar sled	1,500.0
1015	Low beta trailer	0.6**
1030	Bell jar - bottom	200.0
1031	Bell jar - northwest	200.0**
1033	South edge of crater	5.0
1045	South edge of pit	100.0
1048	East edge of downhole cables	900.0
1048	East edge of pit over downhole cables	15,000.0**
1050	Edge of pit - north	150.0
1052	West edge of pit	50.0
1055	Approximately 100 feet SE of pit at gas seals	5,000.0**
1056	20 feet south of gas seals at cable	25.0**
1100	Working area at bell jar - south side	200.0

*This survey was performed by three separate Radsafe teams

**Contact readings

6.3.3 Second Radioactive Effluent Release Situation

Slow seepage from around the SGZ casing began at approximately 1430 hours. RAMS unit readings fluctuated between 1 R/h and 1.8 R/h until about 2000 hours, when readings began to decrease. During this time, Halliburton personnel dressed in anticontamination clothing and MSA masks performed Cal-sealing operations to stop the effluent release. When this operation was completed, all RAMS readings returned to background.

Concurrently, an exposure incident occurred involving an inspection party consisting of two TC/DASA personnel, a representative of EG&G, an SC health physicist, and a Radsafe monitor. At approximately 1430 hours, all party members dressed in coveralls, shoe covers, and gloves, and proceeded to the SGZ pit. No radioactivity had been detected after cavity collapse, so no respiratory protection was required. Upon their approach, gaseous radioactivity began seeping from SGZ as discussed above. This seepage caused inadvertent exposure of the five individuals. Upon exit from the area, all personnel were decontaminated at the Radsafe decontamination facility. Personnel were advised that urinalysis and thyroid counts would be necessary. These were subsequently performed. The maximum thyroid exposure received was 737 mrem. Permissible limits for the thyroid were 10,000 mrem per 13 weeks and 30,000 mrem per year.

Small seepages of radioactive effluent from cracks and fissures around SGZ continued periodically over the next three days. These were sealed with Cal-seal as soon as they were detected.

6.3.4 Cloud Tracking and Sampling

The PHS provided aerial support to determine the magnitude, composition, and trajectory of any radioactive effluent release. Initial monitoring was performed by two PHS monitors in a USAF

U-3A aircraft with USAF pilot and co-pilot. In addition, a Turbo-Beech aircraft (Vegas 8) and crew performed a cloud tracking and cloud sampling mission.

At zero time, the U-3A and Vegas 8 were orbiting the closed area. The U-3A made several passes over SGZ with results as shown in Table 6.3. Ground elevation at SGZ was about 3,400 feet MSL.

Vegas 8 requested clearance to 6,000 feet MSL five miles north of SGZ at 0950 hours to set up a sampling pattern. At 1010 hours, Vegas 8 moved closer and found the leading edge of the cloud about three miles north of SGZ with a reading of 0.06 mR/h. Vegas 8 returned to the five-mile sampling path and did not encounter the cloud, which indicated that the cloud was moving very slowly. The cloud had not reached the sampling path by 1030, but at 1031 hours it was located about four miles north of SGZ. A pass at 1031 hours indicated a peak reading of 0.2 mR/h at 6,000 feet MSL four miles north of SGZ. Subsequent passes indicated a very slow cloud movement onto the Nellis Bombing and Gunnery Range. The cloud appeared to be circular with a diameter of 1-1/2 miles. The cloud entered bombing and gunnery range airspace at 1036 hours, and the first mission was terminated at 1040 hours.

Vegas 8 reentered the area at 1835 hours to monitor and sample radioctive effluent leaking from SGZ. Several horizontal passes were made normal to the hot line five miles from SGZ. The readings obtained are shown in Table 6.4. The effluent was leaking continuously, resulting in a plume about 2,000 feet thick vertically and 1-1/4 miles wide at five miles. Surveillance during the first mission showed an initial short-term release primarily consisting of noble gas activity. The peak exposure rate in the cloud at 1037 hours was 0.2 mR/h four miles north of SGZ. The second mission indicated a continuing release of noble gas activity. Samples taken from 1847 to 1904 hours found xenon-135 in an average concentration of 8.2×10^3 pCi/m^3 (250 curies total

Table 6.3. DIANA MOON event - U-3A monitoring results, 27 August 1968.

Time (Hours)	Altitude (Feet) (MSL)*	Distance from SGZ (miles)	Gamma Exposure Rate (mR/h)
0933	3700	0	0.2
0937	3700	0	80.0
0939	3600	0	160.0
0941	3900	1/4 N	1.0
0943	3500	1/2 N	20.0
0945	4000	1/4 N	40.0
0950	4400	1 N	6.0
0954	3500	0	1.7
1000	3500	1 N	0.8
1009	4700	1 N	1.0

*Elevation of SGZ was 3,400 feet MSL.

Table 6.4. DIANA MOON event - Vegas 8 - aerial monitoring results, 27 August 1968.

Time (Hours)	Altitude (Feet) (MSL)*	Distance from SGZ (miles)	Gamma Exposure Rate (mR/h)
		First Mission	
1010	6000	3	0.06
1031	6000	4	0.02
		Second Mission	
1843	4500	5	0.30
1847	4500	5	0.70
1856	4500	5	0.20
1904	4500	5	0.40

*Elevation at SGZ was 3,400 feet.

release based on a 15 mph wind speed). Radioactive effluent from the event was not detected offsite by ground monitoring.

6.4 POSTEVENT ACTIVITIES

6.4.1 Experiment Recovery Operations

Experiment recovery from the bell jar and sled began on D+1 and continued until 4 September 1968. A preconstructed assembly building was placed (using a crane) over the bell jar and sled. Access to the building was controlled by Radsafe and WSI. Major experiments were then recovered by LMSC and REECo personnel. After all experiments were removed, the sled, bell jar, and instrument spool were decontaminated and placed in storage at the LASL construction yard for possible use on future events.

6.4.2 Postevent Drilling

Postevent drilling on PS-1A began at 1235 hours on 24 September 1968 and was completed at 1115 hours on 25 September. A core sampling operation was conducted between 0755 and 1050 hours on 25 September. Fifteen core samples were extracted with a maximum reading of 450 mR/h in contact with a single sample.

A sidetrack hole, PS-1AS, was begun at 1230 hours on 25 September and completed at 1825 hours the same day. Core sampling was conducted from 1515 to 1715 hours. Twenty-eight core samples were extracted with a maximum contact reading of 240 mR/h for a single sample.

An additional postevent drilling operation (to examine the LOS pipe) was performed from 27 September to 4 October 1968. Photographs of the LOS pipe and containment system were taken while drilling through various closures. A minor release of radioactivity occurred during a cellar survey; however, the location had been previously designated as a radex area and personnel were dressed in anticontamination clothing. The release consisted of small amounts of xenon-133 and xenon-135.

6.4.3 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.
4. DIANA 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 area enclosed by the U1e 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 of a hazardous nature. 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. Maximum readings of 70,000 ppm CO_2, 10,000 ppm CO, and 100 percent LEL of explosive mixtures were measured during experiment recovery activities on 29 August 1968.

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

6.5 RESULTS AND CONCLUSIONS

Telemetry coverage began at 0931 hours on 27 August and continued until 2300 hours on 25 September 1968. The maximum radiation reading was 80 R/h at 0931 hours at the unit located on the bell jar. This reading was attributed to activation products.

Initial radiation surveys were conducted between 0947 hours and 1100 hours on D-day. The maximum reading was 15 R/h at the east edge of the pit over the downhole cables at 1048 hours.

Postevent drilling began at 1235 hours on 24 September and was completed on 4 October 1968. Two postevent core sampling operations and one photographic mission to examine the LOS pipe and containment system were conducted. A total of 43 core samples were extracted with a maximum radiation intensity of 450 mR/h in contact with a single core sample.

Personnel exposures received during individual entries to DIANA MOON radex areas from 27 August 1968 to 4 October 1968 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)	Average Exposure (mR)
All Participants	990	600	7
DOD Participants	68	210	15

CHAPTER 7

HUDSON SEAL EVENT

7.1 EVENT SUMMARY

HUDSON SEAL was a DOD underground test conducted in tunnel U12n.04 at 1005 hours PDT on 24 September 1968 with a yield less than 20 kt (Figure 7.1). Device emplacement was at a vertical depth of 1,130 feet. The objectives of the event were to test materials and equipment in a nuclear detonation environment and to provide a basis for comparison of several environment-measuring techniques. Government agencies and contractors conducted 21 projects to obtain desired weapons effects information. Containment of the HUDSON SEAL event was complete. No radioactive effluent was detected onsite or offsite from this event.

7.2 PREEVENT ACTIVITIES

7.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all HUDSON SEAL project activities in Area 12. 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. LRL was responsible for fielding the device. Sandia Corporation was responsible for reentry and recovery safety. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

Project agencies were responsible for designing, preparing,

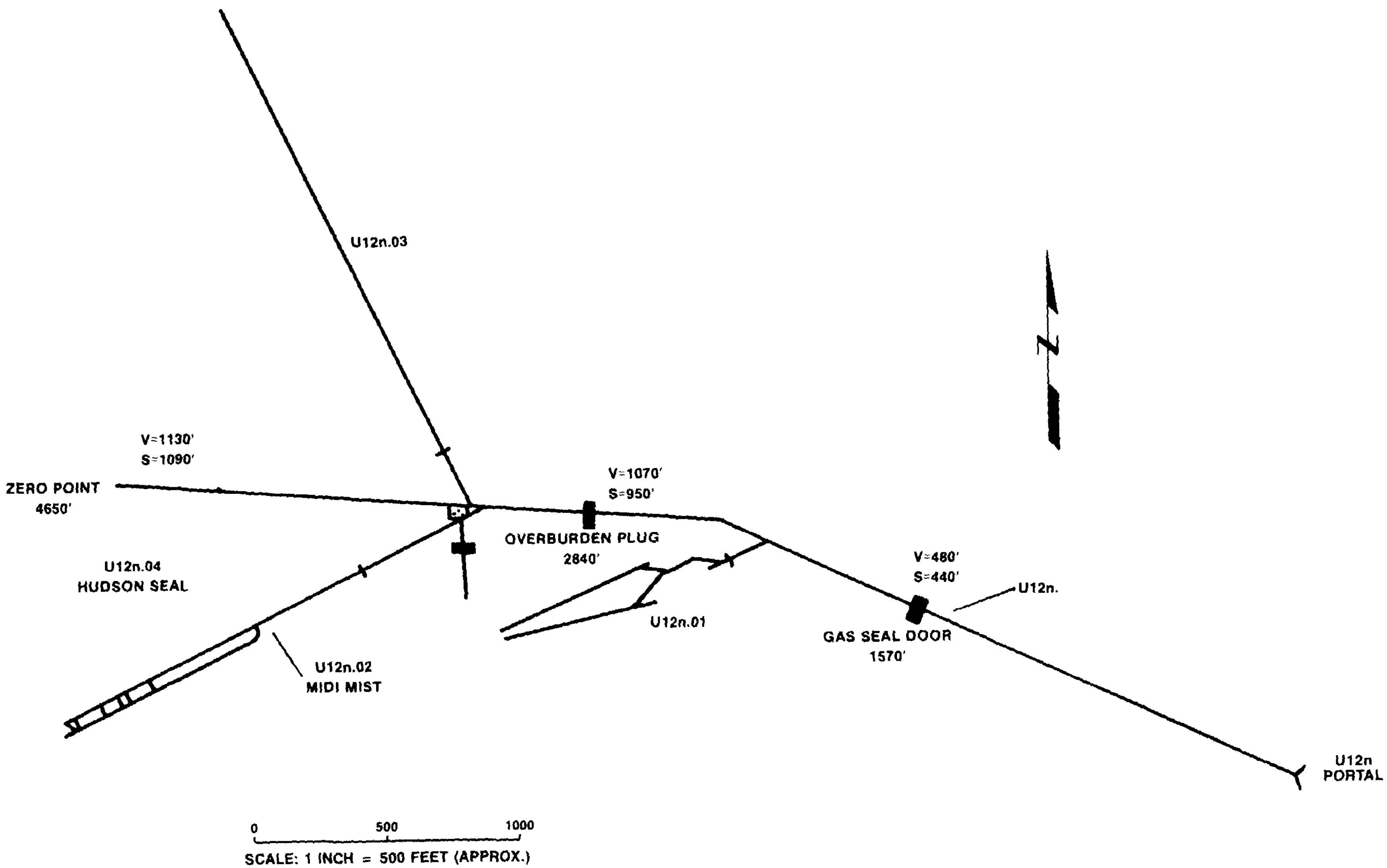

Figure 7.1 HUDSON SEAL event - tunnel layout.

and installing, or delivering their experiments to the installation contractor, and for removal of experiments from the NTS postevent.

The LRL Test Group Director was responsible to the Test Manager for the area 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 Test Manager relieved the LRL Test Group Director of responsibility and delegated responsibility to the DOD Test Group Director.

The DOD Test Group Director and Test Group Staff were assigned from Test Command, DASA. The Technical Director for the scientific program was from the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, and was designated by the Director, DASA. The Safety Director was assigned to the Test Group Staff from LRL.

When in the field at NTS, the DOD Test Group Director reported directly to the Military Deputy Test Manager and was additionally responsible to the AEC Test Manager for all matters affecting the Test Manager's NTS management functions.

7.2.2 Planning and Preparations

A. Radiological Safety Support

A "HUDSON SEAL Operations Plan" was issued in August 1968 to provide information required for planning and conducting the test event. This plan covered project organization and personnel, dry runs, area control, reentry operations, effluent documentation, safety, air operations, reports, and security. Preevent preparation and postevent procedures used to produce safe and economical reentry within the desired time frame were described in a "HUDSON SEAL Reentry Plan." Stemming designs incorporated necessary provisions to maximize reentry safety.

Detailed reentry plans were submitted to participating agencies prior to the test event. Test area maps showing appropriate reference points were prepared. Reentry routes into the test area were established during dry runs. Radiation monitors were briefed regarding surface reentry sample recovery, manned stations, and security station requirements.

Radsafe provided monitoring teams and supervisory personnel for initial surface radiation surveys, aerial surveys, and tunnel reentry parties. Radsafe personnel were stationed at the DOD Test Group Director's FCP to

- perform initial and subsequent ground surveys, as required;
- provide emergency rescue and support as directed;
- provide and issue anticontamination equipment, portable instruments, and dosimetric devices;
- perform personnel, equipment, and vehicle decontamination; and
- operate a sample return station.

Coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape were available for anticontamination purposes.

B. Telemetry and Air Sampling Support

Twenty-eight remote telemetry stations were in operation; 18 on the surface and 10 inside the tunnel (Table 7.1).

Table 7.1. HUDSON SEAL event RAMS unit locations.

Station	Location
	ABOVEGROUND
3	67 feet from portal at 45° azimuth (vent line)
4	67 feet from portal at 45° azimuth (vent line)
6	400 feet from portal at 16° azimuth
7	275 feet from portal at 89° azimuth
8	363 feet from portal at 164° azimuth
10	558 feet from portal at 228° azimuth
11	416 feet from portal at 291° azimuth
12	648 feet from portal at 333° azimuth
17	3,086 feet from portal at 282° azimuth
18	3,110 feet from portal at 289° azimuth
19	3,350 feet from portal at 282° azimuth
20	drill hole building at 288° azimuth
21	3,130 feet from portal at 289° azimuth
22	3,300 feet from portal at 291° azimuth
23	3,490 feet from portal at 288° azimuth
24	500 feet from SGZ AT 120° azimuth
26	500 feet from SGZ at 240° azimuth
27	500 feet from SGZ at 0° azimuth
	UNDERGROUND
32	275 feet (04 drift)
36	2,960 feet (main drift)
36a	2,870 feet (main drift)
37	2,740 feet (main drift)
37a	2,780 feet (main drift)
40	1,701 feet (main drift)
40a	1,616 feet (main drift)
41	1,475 feet (main drift)
42	700 feet (main drift)
43	50 feet (main drift)

Air sampling units were positioned at four surface locations:

2 - Portal
2 - Near downhole cable house on Rainier Mesa

C. Security Coverage

Two muster stations were established. Muster station No. 1 was located at Rainier check point just west of Area 12 Camp, and No. 2 was located on Stockade Wash Road just east of Pahute Mesa Road. Security air sweeps were performed in a U-6A aircraft. Security procedures were in accordance with AEC Manual Chapter 0560, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations."

D. Air Support

One UH-1F helicopter was used by LMAFS personnel for closed-circuit television coverage. Additional UH-1F aircraft were used by DOD personnel for an aerial photo mission and as standby support for the Test Manager. A USAF U-3A aircraft was used by USPHS personnel for cloud tracking purposes. These aircraft were all staged from ISAFAF. Security sweeps were performed using a U-6A aircraft also staged from ISAFAF. In addition, the PHS had available a Turbo-Beechcraft (Vegas 8) for cloud sampling, if needed. The NATS Martin 404 was on standby at McCarran Airport in Las Vegas.

7.2.3 Late Preevent Activities

At 1500 hours on D-1, a readiness briefing was conducted at CP-1. A detonation time of 0930 hours was requested at this briefing.

A final dry run and button up activities were conducted by personnel representing GA, LMSC, LRL, SC, EG&G, AFWL, Kaman Nuclear, GE, SAMSO, SRI, and AVCO.

In accordance with the "Test Manager's Schedule of Events," muster and control stations were established at 1800 hours. Once these were in place, security personnel conducted the first security sweep between 1825 and 2020 hours. A second security check was made from 2200 hours to 2330 hours. After 2400 hours, only persons listed on the "Schedule of Events" or specifically authorized by the Test Manager or Test Group Director were allowed to remain in the closed area.

7.3 EVENT-DAY AND CONTINUING ACTIVITIES

Final security sweeps of Areas 12, 16, 17, 18, 19, 20, and 30 were conducted from 0115 hours to 0500 hours on D-day. At the 0500 readiness briefing, a zero time of 0900 hours or earlier was requested. A scheduled zero time of 0830 hours was subsequently established. Permission to arm the device was granted at 0520 hours. Final countdown began on schedule; however, technical problems were encountered which delayed test execution.

HUDSON SEAL zero time was 1005 hours PDT on 24 September 1968.

7.3.1 Telemetry Coverage

Telemetry measurements were taken from 1006 hours on 24 September to 1600 hours on 27 September 1968. The maximum gamma reading obtained was 800 R/h by RAMS unit No. 32 on 24 September at 1006 hours. Only three underground RAMS units (Nos. 32, 36, 36A) showed readings above background; Nos. 36 and 36A had reached background by 2400 hours on 24 September. RAMS unit No.

32 showed steadily decreasing readings, with a final reading of 17 mR/h when telemetry was secured on 27 September. No radioactivity above background was detected by surface RAMS units.

7.3.2 Radiation Surveys

The initial surface radiation survey began at 1133 hours when Radsafe survey teams No. 3 and 4 were released. Both teams surveyed from the FCP to Rainier Mesa trailer park. This survey was completed at 1220 hours, and no radiation readings above background were detected.

Radsafe survey teams No. 1 and 2 were released at 1248 hours to survey the portal area. All radiation readings were background. This survey was completed at 1355 hours after Radsafe personnel had placed a barricade inside the portal.

7.3.3 Surface Experiment Recovery

DOD personnel were in charge of experiment and data recovery activities during reentry to the Rainier Mesa trailer park and a subsequent reentry to the portal area trailer park.

Reentry and experiment recovery teams entered Rainier Mesa trailer park at 1145 hours on D-day. They had been released shortly after the initial Radsafe survey teams. Film and magnetic tape recovery was performed by participants representing AVCO, GA, LASL, LRL, EG&G, AFWL, SRI, GE, Kaman Nuclear, and DOD. LMSC personnel recovered oscillograph paper and scope camera film. Only background radiation readings were obtained during this experiment recovery operation.

At 1248 hours, teams were released to enter and perform data recovery at the portal trailer park. Magnetic tapes and film were recovered by personnel from GA, LRL, and EG&G. LMSC representatives recovered film, video tape, and temperature charts. Again, only background radiation readings were obtained. All initial surface experiment recovery work was completed by 1335 hours on D-day.

7.4 POSTEVENT ACTIVITIES

7.4.1 Tunnel Reentry Activities and Experiment Recovery

The initial tunnel reentry began at 1030 hours on 25 September (D+1). Team No. 1 went to the gas seal door by means of a train, performing radiation and tunnel damage surveys as they traveled. The tunnel was in good condition, allowing unobstructed passage to the gas seal door. At 1041 hours, they opened the manway door, thus allowing continued access through the tunnel to the overburden plug. After the gas seal door was opened and chained at 1100 hours, it was apparent that railroad tracks beyond the gas seal door were in place. Since there appeared to be no damage to the tracks, reentry to the overburden plug was made by train. Some minor spalling was noted between the gas seal door and the overburden plug. No toxic gas or explosive mixtures were detected and no radiation levels greater than 1 mR/h were measured. The overburden plug was reached at 1205 hours and the team began removing bolts from the overburden plug door, which was opened at 1257 hours. When this was accomplished by 1259 hours, the team began exiting the tunnel, reaching the portal at 1310 hours. Team members were checked for contamination, but no radioactivity was detected.

Reentry team No. 2 entered the tunnel at 1343 hours and traveled by train to the overburden plug. Sandbags and vermiculite had to be removed before the overburden plug could be cleared and opened, all of which was completed at 1410 hours. Reentry team No. 2 exited the tunnel at 1420 hours. No contamination was detected.

At 1450 hours, the Damage Assessment Team (DAT) entered the tunnel to walk out the 02, 03, and 04 drifts. All DAT members wore respiratory protection equipment beyond the overburden plug. Only minor damage was found in the 02 and 03 drifts, and the drain line through the 03 plug was opened. No explosive mixtures or toxic gases were detected. Radiation measurements were less than 1 mR/h. The 04 drift was entered at 1529 hours. Minor damage was observed and a radiation measurement of 200 mR/h was recorded at test chamber No. 1, which was located approximately 1,100 feet from the zero point. The DAT exited the tunnel at 1632 hours. At 1700 hours, reentry party No. 4 entered the tunnel to repair vent lines. Repairs were completed and the team exited the tunnel at 1835 hours. Between 1910 and 2010 hours, reentry party No. 5 entered the tunnel and opened test chamber doors. Operations were secured for the evening at 2010 hours.

Experiment recovery was performed by personnel representing GE, LRL, NDL, SC, EG&G, DOD, LMSC, LASL, NOL, AVCO, NRL, AFWL, MIT, McDonnell-Douglas, and Kaman Nuclear from 26 September through 15 October 1968. The maximum radiation reading obtained during recovery operations was 250 mR/h inside test chamber No. 1 at 1230 hours on 28 September 1968. No alpha radiation was detected. The maximum toxic gas concentration detected was 50 ppm CO in test chambers No. 1 and 2. Although mineback operations continued through November, experiment recovery was essentially complete in mid-October.

7.4.2 Offsite Radiation Surveillance

The PHS had air samplers operating at 104 routine stations at offsite locations. Fifteen PHS personnel were on duty for surveillance activities for this event, and aerial monitoring was performed by the PHS cloud tracking team in an Air Force U-3A aircraft. One PHS Turbo-Beech aircraft was standing by in Las Vegas to undertake a cloud sampling mission and supplement cloud tracking if needed.

No radioactivity above normal 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. No fresh fission products were detected in any environmental sample collected offsite throughout this period, and no prefilter air samples contained levels of gross beta activity above normal background.

7.4.3 Industrial Safety

Industrial safety codes, including specific codes for drilling, were established by REECo and were 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 Material Command Regulations (AMCR 385-224).
2. AEC Manual 500 Series for the Nevada Test Site.
3. Individual Safe Operating Procedures.
4. DIANA 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 approved by the DOD Safety Coordinator.

7.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1006 hours on 24 September 1968 and ended at 1600 hours on 27 September 1968. The maximum gamma reading obtained was 800 R/h by RAMS unit No. 32 at 1006 hours on 24 September 1968. This unit was located behind the blast plug at 275 feet in the 04 drift.

The initial surface radiation survey began at 1133 hours and ended at 1220 hours on 24 September. No radiation levels above background were detected.

The initial underground radiation survey began at 1030 hours and ended at 1632 hours on 25 September. The maximum gamma exposure rate measured was 200 mR/h at test chamber No. 1. No alpha radiation was detected. The maximum toxic gas concentration measured was 50 ppm CO in test chambers No. 1 and 2. The maximum gamma exposure rate reading during recovery operations was 250 mR/h inside test chamber No. 1 at 1230 hours on 28 September.

There were no whole-body external or internal exposures which exceeded established guidelines.

Personnel exposures received during individual entries to HUDSON SEAL radex areas from 24 September 1968 to 4 December 1968 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)	Average Exposure (mR)
All Participants	791	240	11
DOD Participants	238	0*	15

*No positive exposures were detected by film badges. The minimum detectable exposure by film badge was 30 mrem.

CHAPTER 8

MING VASE EVENT

8.1 EVENT SUMMARY

MING VASE, a DOD underground test with a yield less than 20 kt, was conducted at 1000 hours PST on 20 November 1968 at tunnel site U16a.04 in Area 16 of the NTS. The LASL-provided device was emplaced at a vertical depth of 1,010 feet (Figure 8.1). The objective of this test was to evaluate the response of material and equipment to a nuclear detonation environment. Government agencies and contractors conducted 18 projects to obtain desired weapons effects information.

Containment of the MING VASE event was complete. No radioactive effluent was detected onsite or offsite from this event.

8.2 PREEVENT ACTIVITIES

8.2.1 Responsibilities

The DOD Test Group Director had responsibility for safe conduct of all MING VASE project activities in Area 16. 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. Because LASL fielded the test device, the LASL Test Group Director was responsible to the Test Manager for the area within a 4,500-foot radius of SGZ. This responsibility was in effect from the time the device was moved to the emplacement site until device detonation. At zero hour the Test Manager relieved the LASL Test Group Director of responsibility and delegated

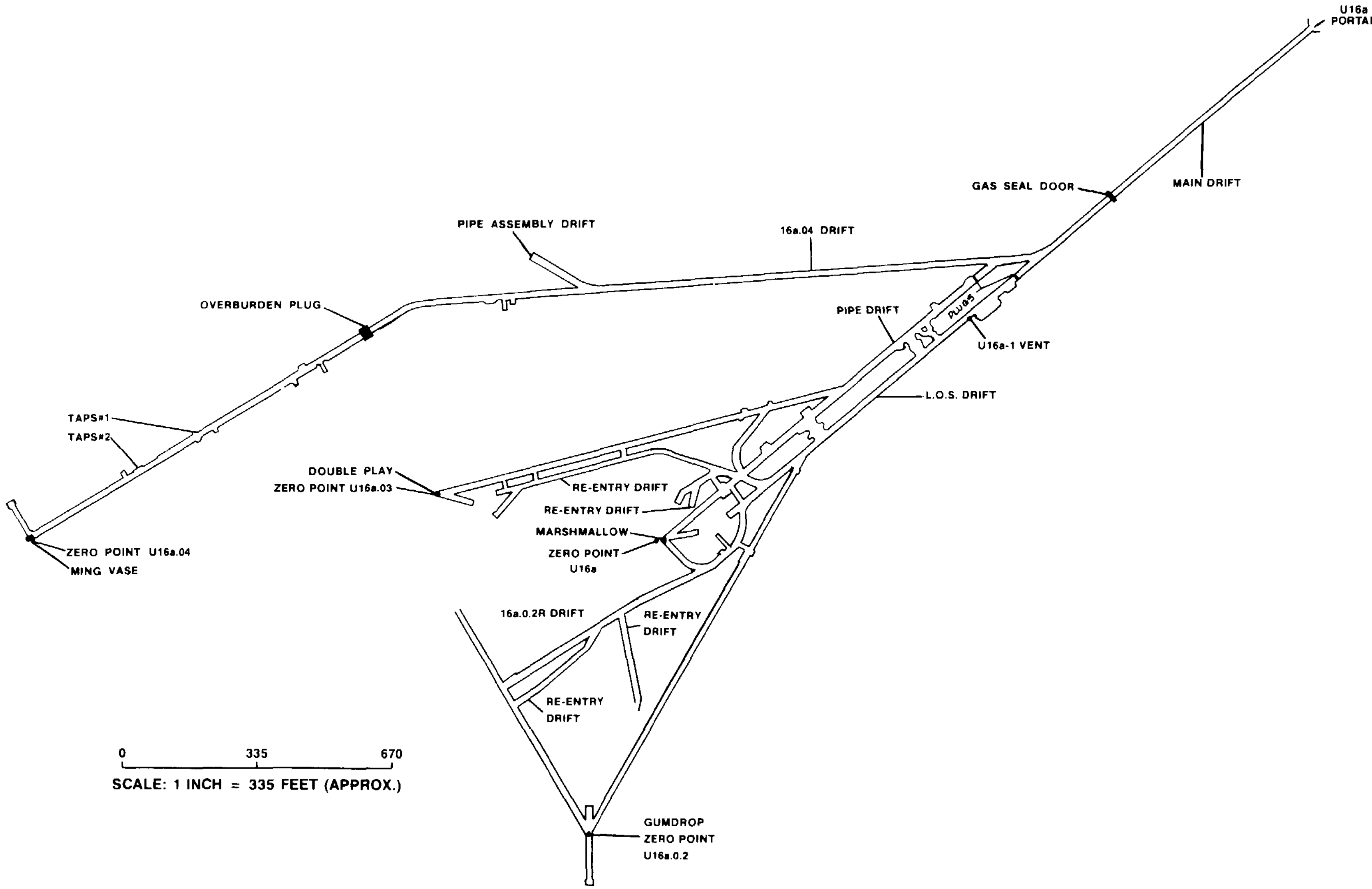

Figure 8.1 MING VASE event - tunnel layout.

responsibility to the DOD Test Group Director. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

8.2.2 Planning and Preparations

The "MING VASE Reentry Plan" described preevent preparations and postevent procedures used to assure a safe and economical reentry. In addition, Radsafe personnel were provided with "Detailed Initial Reentry Procedures" for reentry and recovery operations. Stemming design incorporated provisions to maximize reentry safety.

A. Radiological Safety Support

Participating agencies were provided with detailed radiological safety reentry plans prior to the test event. Test area maps with appropriate reference points were prepared. Reference markers and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs."

Radiation monitors were briefed regarding reentry, sample recovery, manned stations, and security station requirements. All personnel at manned stations were provided with anticontamination clothing and equipment, and Radsafe monitors were in attendance.

A mobile issue facility for anticontamination clothing, respiratory devices, instruments, and dosimetric devices was positioned prior to the event at the security barricade near the FCP. A personnel and vehicle decontamination facility was established adjacent to the mobile issue facility.

Radsafe monitors were stationed at all WSI security roadblocks and work areas within the exclusion area to perform surveys and provide other support as directed.

Monitoring teams and supervisory personnel for initial surface radiation surveys, helicopter surveys, and tunnel reentry parties were provided. Radsafe personnel were stationed at the DOD Test Group Director's FCP to perform initial and subsequent ground surveys as required and provide emergency rescue and support as directed; provide and issue anticontamination equipment, portable instruments, and dosimetric devices; perform personnel, equipment, and vehicle decontamination; and operate a sample return station.

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

B. Telemetry and Air Sampling Support

Seventeen remote telemetry radiation monitoring stations provided coverage for the MING VASE event (Table 8.1).

Four air samplers were placed in an array at the portal and SGZ, and were calibrated and operational at zero time. Two units were located 500 feet from SGZ at 25° azimuth, one was 381 feet from the portal at 34° azimuth, and one was 50 feet from the portal at 5° azimuth.

PHS had 105 air samplers operating at offsite locations. Twenty personnel were on duty for offsite surveillance activities.

Table 8.1. MING VASE event RAMS unit locations.

Station	Location
	ABOVEGROUND
1	Portal
2	205 feet from portal at 305° azimuth
3	381 feet from portal at 34° azimuth
4	430 feet from portal at 78° azimuth
5	325 feet from portal at 147° azimuth
6	160 feet from portal at 281° azimuth
7	270 feet from portal at 311° azimuth
8	300 feet from portal at 86° azimuth
11	600 feet from portal at 253° azimuth
12	2,240 feet from portal at 48° azimuth
16	500 feet from SGZ at 157° azimuth
17	500 feet from SGZ at 253° azimuth
18	500 feet from SGZ at 25° azimuth
	UNDERGROUND
27	1,964 feet inside 04 drift
28a	1,780 feet inside 04 drift
32a	56 feet inside 04 drift
35	200 feet in from portal in main drift

C. Security Coverage

All personnel entering or exiting the controlled area were required to stop at muster or control stations for issuance or return of appropriate badges. All personnel were required to have proper security clearances for the area. Control of the area was maintained by the use of roadblocks, access authorizations, and a "Schedule of Events." Parties could enter the controlled area only if they were listed on the "Test Manager's Schedule of Events" or had the permission of the Test Group Director. WSI security guards were responsible for activating roadblocks to direct traffic flow.

D. Air Support

Aircraft support for this event was as follows:

Type	Organization	Mission
U-6A	Security	D-day Safety Sweep
UH-1F	LMAFS	Aerial CCTV Coverage
UH-1F	USAF/Test Manager	Emergency Standby
U-3A	USAF/USPHS	Cloud Tracking
Turbo-Beech	USPHS	Cloud Sampling
Turbo-Beech	USPHS	Cloud Sampling*
Martin 404	EG&G/NATS	Cloud Tracking*
Cessna 206	AAS	Postevent Survey

*On Standby at McCarran Airport, Las Vegas, Nevada

8.2.3 Late Preevent Activities

A readiness briefing was held at 1430 hours on D-1. Experimenters were in the closed area all day performing button up activities. Experimenter organizations represented were AFWL, KN, LASL, SC, GE, SRI, BAC, LRL, EG&G and DOD.

The first security sweep of the closed area was conducted before 2400 hours on D-1.

8.3 EVENT-DAY AND CONTINUING ACTIVITIES

After a second security sweep of the closed area was completed at 0500 hours on D-day, the final readiness briefing for the Test Manager and Advisory Panel was conducted at 0800 hours. At 0805 hours permission to arm the device was granted. WSI personnel then conducted a final security sweep which was completed at 0845 hours. The arming party was out of the closed area and the area secured by 0900 hours. Manned photo station personnel were in their assigned positions at 0945 hours.

MING VASE zero time was 1000 hours PST on 20 November 1968.

Telemetry measurements began at 1001 hours on 20 November and ended at 1600 hours on 23 November 1968. At 1001 hours, a maximum gamma intensity of 325 R/h was measured by underground RAMS unit No. 27, which was located 1,964 feet inside the 04 drift of U16a.

8.3.1 Surface Reentry Activities and Experiment Recovery

Initial surface safety and radiological surveys were performed under the direction of the Test Group Director in accordance with the "Radiological Safety Support Plan for MING VASE." Initial survey teams were released by the Test Group Director at 1042 hours and the initial survey was completed at 1105 hours. Initial survey results were background.

All survey data were reported to the net 3 radio control operator when measurements were made. Plotting facilities were maintained at the FCP and CP-1. Radsafe control was located in the operations trailer at FCP where sufficient personnel were standing by to provide rescue and emergency support, and radiological area control as radex areas were established.

Experiment recovery on the surface began at 1112 hours on D-day. Those organizations recovering data from trailers at the portal area were SC, LASL, EG&G, SRI, LRL, AVCO, BAC, LMSC, AFWL, KN, and GE. Film, tape, and instrument recovery was accomplished without encountering detectable radiation. Surface experiment recovery operations were completed on 3 December 1968.

8.3.2 Initial Tunnel Reentry

Tunnel ventilation was established at 1325 hours on 20 November. By 1450 hours, the muster station and the Radsafe Base Station had been moved to the portal area.

Since there appeared to be no radiological or industrial hygiene hazards, it was decided that the tunnel reentry team members would not wear Scott-Draeger breathing equipment when they attempted to open the gas seal door, but would carry MSA all-purpose masks. Initial reentry began at 1530 hours. The reentry team arrived at the gas seal door at 1534 hours, having found the tunnel to be in good condition. The gas seal door was opened at 1610 hours. A maximum radiation reading of 4 mR/h was obtained just inside the manway door. This was residual radioactivity from a previous event. No explosive mixtures or toxic gases were detected.

At 1625 hours, the initial tunnel reentry team began its exit. No further tunnel reentry activities were conducted on 20 November 1968.

8.4 POSTEVENT ACTIVITIES

8.4.1 Tunnel Reentry and Experiment Recovery

Tunnel reentry activities began again at 0910 hours on 21 November when reentry team No. 1 entered the tunnel complex to open the overburden plug door. By 1015 hours the overburden plug was opened; the radiation reading measured at this location was 4 mR/h beta plus gamma, and no explosive mixtures or toxic gases were detected. Upon reaching test chamber No. 1 at 1030 hours, readings were again recorded. A reading of 250 mR/h was obtained in contact with the door at test chamber No. 1. The manhole located twenty feet from the zero point side of test chamber No. 1 read 60 mR/h with 10,000 ppm CO and 90 percent of the LEL for explosive mixtures detected. The test chamber No. 1 door was opened at 1050 hours. Greater than 10,000 ppm CO and 100 percent of the LEL for explosive mixtures were measured. Team No. 1 returned to the portal area at 1100 hours.

Reentry team No. 2 entered the tunnel at 1245 hours and reestablished ventilation to the test chambers. The maximum exposure rate reading obtained at this time was 150 mR/h outside test chamber No. 1. Team No. 2 exited the tunnel at 1335 hours.

At 1504 hours on 21 November, a third reentry team and an LRL experiment recovery party reentered the tunnel beyond the overburden plug. A radiation reading of 200 mR/h was obtained outside the door of test chamber No. 1, and 100 ppm CO was measured. The LRL recovery party completed recoveries and reassembled at the overburden plug with reentry team No. 3. All personnel exited the tunnel at 1600 hours, and operations were secured for the day.

The LOS pipe was walked out on 22 November. A maximum reading of 4 mR/h at TAPS No. 1 was obtained.

After all tunnel surveys were completed and the ventilation system was operational, personnel from experimenter organizations, accompanied by Radsafe monitors, were allowed to enter the tunnel and perform experiment recovery operations. Those personnel performing recovery tasks were from SC, SRI, GE, GA, SWC, LRL, LMSC and DOD. Experiment recoveries proceeded as planned with no radiation problems encountered. Recovery operations went smoothly; experiments were recovered from the tunnel and LOS pipe, and the operation was terminated on 17 January 1969.

8.4.2 Postevent Drilling

Drilling on PS-1V began at 1255 hours on 9 December 1968. After encountering several problems with drilling equipment, sufficient depth was reached to begin the core sampling operation at 1320 hours on 10 December. This operation was completed at 1800 hours. The maximum gamma exposure rate measured during drillback operations was 0.2 mR/h at 2330 hours. Thirty-three core samples were taken with a maximum reading for a single sample of 5 R/h at contact. Directional surveys and gamma logging were performed during the operation. Eight RAMS units were in operation during drillback. They were located at 45° intervals beginning at 22.5° on a 900-foot-radius circle around the drill hole. No toxic gases were detected.

Postevent drilling was completed and the ball valve closed at 2335 hours on 10 December 1968. No abandonment valve or blind flange was installed. This allowed for possible future use of the drill hole as a vent line for mining operations.

8.4.3 Industrial Safety

Sand stemming and plugs with blast doors had been emplaced in the tunnel. The plugs provided containment, reduced radioactivity in the reentry area, and minimized reentry problems.

Blast doors contained any debris that might pass the stemming. Radiation sensing instruments provided remote detection of tunnel radiation levels while tunnel condition indicators remotely monitored the condition of the tunnel.

Reentry was not made beyond ventilation, 1,000 ppm CO, or 10 percent LEL of explosive gas mixtures.

Checks were made on each shift for radiation levels, toxic gases, and explosive mixtures. These measurements were then recorded in the monitors' log book. Maximum industrial hygiene readings for the MING VASE event were:

1. 100 percent of the LEL inside of test chamber No. 1 on 21 November 1968;

2. 20,000 ppm CO behind the TAPS door on 9 December 1968;

3. 7,000 ppm CO_2 behind the TAPS door on 9 December 1968; and

4. 1 ppm $NO+NO_2$ at Sample Protection Station (SPS) No. 1 on 3 January 1969.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes, including specific codes for mining, tunneling, and drilling, were established by REECo and were emphasized during all operations.

All explosives and all electro-explosive components, toxic materials or radioactive materials were handled, stored, and transported in accordance with the applicable section of the Army Material Command Regulations (AMCR-385-224), NTS-SOPs, and all revisions thereto.

The portal construction area and the tunnel were hard hat and foot protection (safety shoes, safety boots, miners boots or toe guards) areas. Each participating agency provided its own safety equipment.

Eye protection, safety glasses or cover-all goggle type, was worn whenever explosives of any configuration were being handled. Conductive booties were worn over shoes at all times in the Explosive Assembly Building. Conductive safety shoes could be worn in lieu of the conductive booties provided they had not been worn on gravel or dirt surfaces.

8.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1001 hours on 20 November 1968 and ended at 1600 hours on 23 November 1968. The maximum gamma exposure rate measured was 325 R/h at 1001 hours on 20 November 1968 by the unit located 1,964 feet inside the 04 drift of U16a.

Initial reentry radiation survey teams entered the controlled area at 1042 hours and performed a survey. This survey operation was completed at 1105 hours on 20 November 1968. Only background gamma exposure rates were measured. No alpha radiation was detected.

Postevent drilling began at 1255 hours on 9 December 1968 and was completed at 2335 hours on 10 December. The maximum gamma exposure rate measured during drillback operations was 0.2 mR/h following completion of coring operations at 2330 hours on 10 December. The maximum intensity at contact with a single core sample was 5 R/h. No alpha radiation was detected.

Postevent operations were completed on 17 January 1969.

Personnel exposures received during individual entries to MING VASE radex areas from 20 November 1968 to 17 December 1968 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)	Average Exposure (mR)
All Participants	675	85	3
DOD Participants	170	85	4

REFERENCE LIST

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.

PREFACE

1. Office of Public Affairs, U.S. Department of Energy, Nevada Operations Office, "Announced United States Nuclear Tests," NVO-209 (Rev. 4), January 1984*

2. Devine, Robert A., Blowing on the Wind: The Nuclear Test Ban Debate, Oxford University Press, NY, 1978

3. Harris, P.S., et al., Defense Nuclear Agency, OPERATION PLUMBBOB, DNA 6005F, 15 September 1981*

4. U.S. Senate Committee on Veterans' Affairs, "Veterans' Claims for Disabilities from Nuclear Weapons Testing," U.S. Government Printing Office, Washington, DC, 1979

Chapter 1, INTRODUCTION

DOE/NV, "Announced Nuclear Tests," (n. 1).
Devine, "Nuclear Test Ban Debate," (n. 2).

5. Weapons Effects Test Group, Field Command, Defense Atomic Support Agency, "Orientation, Nevada Test Site," January 1962

6. Weapons Test Division, Defense Atomic Support Agency, "Orientation, Nevada Test Site," revised 15 August 1964

7. Ponton, Jean, et al., Defense Nuclear Agency, OPERATION DOMINIC II, DNA 6027F, 31 January 1983*

Chapter 2, UNDERGROUND TESTING PROCEDURES

8. Liverman, James L., Energy Research & Development Administration, Final Environmental Impact Statement, Nevada Test Site, Nye County, Nevada, ERDA - 1551, September 1977*

9. Butkovich, Theodore R., Lawrence Radiation Laboratory, University of California, Effects of Water Saturation on Underground Nuclear Detonations, UCRL-51110, 9 September 1971*

Committee on Veterans Affairs, "Claims for Disabilities," (n. 4), on venting.

10. Radiological Sciences Department, Reynolds Electrical & Engineering Co., Inc., "Standard Operating Procedures," January 1961-1968

EVENT SUMMARIES AND EACH EVENT CHAPTER

11. Atomic Energy Commission, Nevada Operations Office, NVOO Completion Report, Operation Crosstie, 1 July 1967 through 30 June 1968, NVO-42, June 1969, Unpublished.

12. Atomic Energy Commission, Nevada Operations Office, NVOO Completion Report, Operation Bowline, 1 July 1968 through 30 June 1969, NVO-66, January 1970, 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 user (see Testing Organizations) Test Director 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.
Bell Jar	Test chamber used on vertical LOS system events.
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 1953 atmospheric test series, located at the NW corner of Area 3 on the NTS. Previously called the "Y."
Blast Door	May be in blast plug, but originally was in its own keyed plug toward the portal from the blast plug. Evolved into an overburden plug with a large steel door containing a smaller access hatch and designed to withstand up to 1000 psi overpressure. May be welded or

	bolted closed during detonation. Sometimes a loosely used substitute term for a gas seal door.
Blast Plug	Barrier constructed underground as a primary containment feature. May be constructed with sandbags (see Sandbag Plugs), solid sand backfill, concrete (see Keyed Concrete Plug), or other materials. Some plugs may have openings through them that are sealed with blast doors, and sometimes sandbags are added to protect the opening temporarily during detonation.
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 or reentry 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.
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.
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.

Coaxial Cable	A single conductor cable with outer shield used for fast or high frequency signals (as oscilloscopes, etc.).
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.
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.
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.

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.
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.
Explosive-Proof Flashlight	A flashlight constructed in such a manner that its use will not cause or create an explosion in an explosive gas atmosphere.
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.
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 Log	Instrument used to measure natural radiation levels in a preemplacement hole, and after an event to measure radiation in the cavity.
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.
Gas Seal Door	A steel door on the portal side of the gas seal plug. It is closed during buttonup 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.
Geophones	Electronic instruments which detect and record rock falls and earth movements by the use of sound.
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.
Instrument Spool	Instrument package placed beneath bell jar on a vertical LOS pipe system. Instrument package was placed within a pipe which looked like a spool.
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, di-

rectly 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.
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.

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.
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 de-

	vice 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.
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.
Pipe String	Consists of pieces of drill pipe that are added as drilling continues.
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 estab-

	lish 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.
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.
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 hundred feet if fractional. Scientific Station 650 is expressed as SS650; Scientific Station 390.65 is expressed as SS390.65.
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 layers loosening 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.
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 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.
2-Hour McCaa Breathing Apparatus	A self-contained respiratory device that supplies two hours of breathing oxygen.
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 debris 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 third volume of DOD underground testing reports. Additional information and definitions may be found in the text and in the Glossary of Terms.

AAS	American Aerial Survey
AEC	Atomic Energy Commission
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AFTAC	Air Force Technical Applications Center
AFWL	Air Force Weapons Laboratory
AMC	Army Material Command
APC	Army Pictorial Center
APS	Army Pictorial Services
ARMS	Aerial Radiation Monitoring System
AVCO	AVCO Corporation
BAC	Boeing Aircraft Corporation
Bkg	Background Radiation Measurement
BJY	BUSTER-JANGLE roads intersection
BRL	Ballistics Research Laboratory
BTL	Bell Telephone Laboratories
CCTV	Closed Circuit Television
CDC	Center for Disease Control
CETO	Civil Effects Test Organization
CIC	Coordination and Information Center
CO	Carbon monoxide
CO_2	Carbon dioxide
CP-1	Control Point Building 1
CP-2	Control Point Building 2
cps	Counts per second
CTO	Continental Test Organization
D-Day	The day a nuclear detonation takes place
DASA	Defense Atomic Support Agency
DAT	Damage Assessment Team
DF	Distribution Factor
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
dpm	Disintegrations per minute
EDT	Eastern Daylight Time
EG&G	EG&G, Inc. (formerly Edgerton, Germeshausen, & Grier)
ERDA	Energy Research and Development Administration

FCDASA	Field Command, Defense Atomic Support Agency
FCDNA	Field Command, Defense Nuclear Agency
FCP	Forward Control Point
FCWT	Field Command Weapons Effects and Tests Group
F&S	Fenix & Scisson, Inc.
FPFF	Full Power Full Frequency
GA	General Atomic Corporation
GE	General Electric Corporation
GM	Geiger-Mueller
GZ	Ground Zero
HAC	Hughes Aircraft Company
HDL	Harry Diamond Laboratories
HE	High explosives (conventional)
H&N	Holmes & Narver, Inc.
ICC	Interstate Commerce Commission
ISAFAF	Indian Springs Air Force Auxiliary Field (formerly ISAFB)
ISAFB	Indian Springs Air Force Base
ISO	Isotopes, Incorporated
JCS	Joint Chiefs of Staff
KN	Kaman Nuclear
kt	Kilotons
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory (now Los Alamos National Laboratory)
LEL	Lower explosive limit
LLNL	Lawrence Livermore National Laboratory
LMAFS	Lookout Mountain Air Force Station
LMSC	Lockheed Missile and Space Corporation
LOS	Line-of-sight
LRL	Lawrence Radiation Laboratory (now Lawrence Livermore National Laboratory)
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
NB	Nevada Branch
NC	Northrup Corporation
NDL	Army Chemical Corps Nuclear Defense Laboratory
NOB	Nevada Operations Branch
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
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
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 station
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
SAMSO	Space and Missile Systems Organization
SC	Sandia Corporation (now Sandia National Laboratories)
SGZ	Surface Ground Zero
SL	Sandia Laboratories (now Sandia National Laboratories)
SNL	Sandia National Laboratories
SOP	Standard operating procedures
SRI	Stanford Research Institute
STWT/DASA	Weapons Test Division/Defense Atomic Support Agency
SWC	Special Weapons Center
TAPS	Tunnel and Pipe Seal
TC	Test Controller
TCDASA	Test Command, Defense Atomic Support Agency
TCWT	Test Command, Weapons Effects & Test Group
TGD	Test Group Director
TNT	High explosive chemical (trinitrotoluene)
TTR	Tonopah Test Range
USAF	United States Air Force
VA	Veterans Administration
WES	Waterways Experiment Station
WSI	Wackenhut Services, Incorporated

APPENDIX C

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

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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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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. Communications

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

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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.

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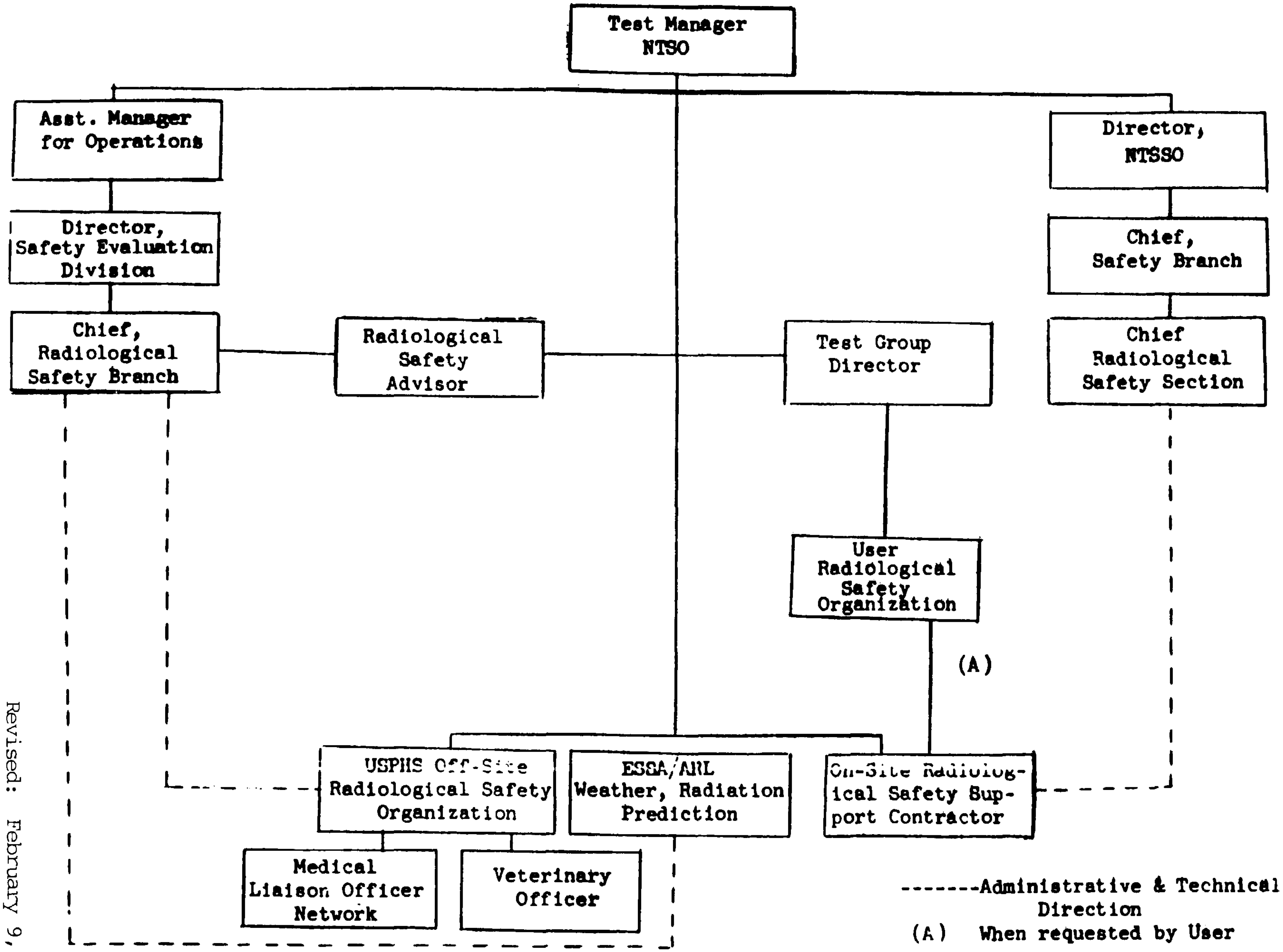

Figure I. Organization Chart
Radiological Safety Activities

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.

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	Dose 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.

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[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.

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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.

Revised: February 9, 1968

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	$6x10^{-9}$	$1x10^{-3}$	$2x10^{-10}$	$4x10^{-5}$
		I	$6x10^{-9}$	$1x10^{-3}$	$2x10^{-10}$	$4x10^{-5}$
	Bi 212	S	$1x10^{-7}$	$1x10^{-2}$	$3x10^{-9}$	$4x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-2}$	$7x10^{-9}$	$4x10^{-4}$
Bromine (35)	Br 82	S	$1x10^{-6}$	$8x10^{-3}$	$4x10^{-8}$	$3x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
Cadmium (48)	Cd 109	S	$5x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
		I	$7x10^{-8}$	$5x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Cd 115m ...	S	$4x10^{-8}$	$7x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
		I	$4x10^{-8}$	$7x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
	Cd 115	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
Calcium (20)	Ca 45	S	$3x10^{-8}$	$3x10^{-4}$	$1x10^{-9}$	$9x10^{-6}$
		I	$1x10^{-7}$	$5x10^{-3}$	$4x10^{-9}$	$2x10^{-4}$
	Ca 47	S	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$5x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$3x10^{-5}$
Californium (98)	Cf 249	S	$2x10^{-12}$	$1x10^{-4}$	$5x10^{-14}$	$4x10^{-6}$
		I	$1x10^{-10}$	$7x10^{-4}$	$3x10^{-12}$	$2x10^{-5}$
	Cf 250	S	$5x10^{-12}$	$4x10^{-4}$	$2x10^{-13}$	$1x10^{-5}$
		I	$1x10^{-10}$	$7x10^{-4}$	$3x10^{-12}$	$3x10^{-5}$
	Cf 251	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$4x10^{-6}$
		I	$1x10^{-10}$	$8x10^{-4}$	$3x10^{-12}$	$3x10^{-5}$
	Cf 252	S	$6x10^{-12}$	$2x10^{-4}$	$2x10^{-13}$	$7x10^{-6}$
		I	$3x10^{-11}$	$2x10^{-4}$	$1x10^{-12}$	$7x10^{-6}$
	Cf 253	S	$8x10^{-10}$	$4x10^{-3}$	$3x10^{-11}$	$1x10^{-4}$
		I	$8x10^{-10}$	$4x10^{-3}$	$3x10^{-11}$	$1x10^{-4}$
	Cf 254	S	$5x10^{-12}$	$4x10^{-6}$	$2x10^{-13}$	$1x10^{-7}$
		I	$5x10^{-12}$	$4x10^{-6}$	$2x10^{-13}$	$1x10^{-7}$
Carbon (6)	C 14	S	$4x10^{-6}$	$2x10^{-2}$	$1x10^{-7}$	$8x10^{-4}$
	(CO_2)	Sub	$5x10^{-5}$	....	$1x10^{-6}$	....
Cerium (58)	Ce 141	S	$4x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$2x10^{-7}$	$3x10^{-3}$	$5x10^{-9}$	$9x10^{-5}$
	Ce 143	S	$3x10^{-7}$	$1x10^{-3}$	$9x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$4x10^{-5}$
	Ce 144	S	$1x10^{-8}$	$3x10^{-4}$	$3x10^{-10}$	$1x10^{-5}$
		I	$6x10^{-9}$	$3x10^{-4}$	$2x10^{-10}$	$1x10^{-5}$
Cesium (55)	Cs 131	S	$1x10^{-5}$	$7x10^{-2}$	$4x10^{-7}$	$2x10^{-3}$
		I	$3x10^{-6}$	$3x10^{-2}$	$1x10^{-7}$	$9x10^{-4}$
	Cs 134m ...	S	$4x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$6x10^{-3}$
		I	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
	Cs 134	S	$4x10^{-8}$	$3x10^{-4}$	$1x10^{-9}$	$9x10^{-6}$
		I	$1x10^{-8}$	$1x10^{-3}$	$4x10^{-10}$	$4x10^{-5}$
	Cs 135	S	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$9x10^{-8}$	$7x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Cs 136	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$9x10^{-5}$
		I	$2x10^{-7}$	$2x10^{-3}$	$6x10^{-9}$	$6x10^{-5}$

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)
	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.

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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)
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 .... (T/2=9.2 hrs)	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}
	Eu 152 .... (T/2=13 yrs)	S	1×10^{-8}	2×10^{-3}	4×10^{-10}	8×10^{-5}
		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	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
		I	3×10^{-8}	3×10^{-3}	1×10^{-9}	9×10^{-5}
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}
		I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Irididum (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}	....	1×10^{-7}	
	Kr 85	Sub	1×10^{-5}	....	3×10^{-7}	
	Kr 87	Sub	1×10^{-6}	....	2×10^{-8}	
	Kr 88	Sub	1×10^{-6}	....	2×10^{-8}	
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-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)
	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.

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		Table II	
			Column 1	Column 2	Column 1	Column 2
			Air (μCi/ml)	Water (μCi/ml)	Air (μCi/ml)	Water (μCi/ml)
	Ra 226	S	$3x10^{-11}$	$4x10^{-7}$	$3x10^{-12}$	$3x10^{-8}$
		I	$5x10^{-11}$	$9x10^{-4}$	$2x10^{-12}$	$3x10^{-5}$
	Ra 228	S	$7x10^{-11}$	$8x10^{-7}$	$2x10^{-12}$	$3x10^{-8}$
		I	$4x10^{-11}$	$7x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
Radon (86)	Rn 220	S	$3x10^{-7}$	....	$1x10^{-8}$	
	Rn 222[3]		$3x10^{-8}$	....	$3x10^{-9}$	
Rhenium (75)	Re 183	S	$3x10^{-6}$	$2x10^{-2}$	$9x10^{-8}$	$6x10^{-4}$
		I	$2x10^{-7}$	$8x10^{-3}$	$5x10^{-9}$	$3x10^{-4}$
	Re 186	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$5x10^{-5}$
	Re 187	S	$9x10^{-6}$	$7x10^{-2}$	$3x10^{-7}$	$3x10^{-3}$
		I	$5x10^{-7}$	$4x10^{-2}$	$2x10^{-8}$	$2x10^{-3}$
	Re 188	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
Rhodium (45)	Rh 103m ...	S	$8x10^{-5}$	$4x10^{-1}$	$3x10^{-6}$	$1x10^{-2}$
		I	$6x10^{-5}$	$3x10^{-1}$	$2x10^{-6}$	$1x10^{-2}$
	Rh 105	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Rubidium (37)	Rb 86	S	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
		I	$7x10^{-8}$	$7x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
	Rb 87	S	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$7x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
Ruthenium (44)	Ru 97	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-6}$	$1x10^{-2}$	$6x10^{-8}$	$3x10^{-4}$
	Ru 103	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$8x10^{-8}$	$2x10^{-3}$	$3x10^{-9}$	$8x10^{-5}$
	Ru 105	S	$7x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
	Ru 106	S	$8x10^{-8}$	$4x10^{-4}$	$3x10^{-9}$	$1x10^{-5}$
		I	$6x10^{-9}$	$3x10^{-4}$	$2x10^{-10}$	$1x10^{-5}$
Samarium (62)	Sm 147	S	$7x10^{-11}$	$2x10^{-3}$	$2x10^{-12}$	$6x10^{-5}$
		I	$3x10^{-10}$	$2x10^{-3}$	$9x10^{-12}$	$7x10^{-5}$
	Sm 151	S	$6x10^{-8}$	$1x10^{-2}$	$2x10^{-9}$	$4x10^{-4}$
		I	$1x10^{-7}$	$1x10^{-2}$	$5x10^{-9}$	$4x10^{-4}$
	Sm 153	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$8x10^{-5}$
Scandium (21)	Sc 46	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-8}$	$1x10^{-3}$	$8x10^{-10}$	$4x10^{-5}$
	Sc 47	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
	Sc 48	S	$2x10^{-7}$	$8x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
Selenium (34)	Se 75	S	$1x10^{-6}$	$9x10^{-3}$	$4x10^{-8}$	$3x10^{-4}$
		I	$1x10^{-7}$	$8x10^{-3}$	$4x10^{-9}$	$3x10^{-4}$
Silicon (14)	Si 31	S	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$9x10^{-4}$
		I	$1x10^{-6}$	$6x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope		Table I		Table II	
			Column 1 Air (μCi/ml)	Column 2 Water (μCi/ml)	Column 1 Air (μCi/ml)	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.

Revised: February 9, 1968

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.

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:

$$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \frac{C_C}{MPC_C} \leqq 1$$

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		Table II	
	Column 1 Air (μCi/ml)	Column 2 Water (μCi/ml)	Column 1 Air (μCi/ml)	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 II, 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.

$$\text{i.e. } \frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \dots \leq \frac{1}{4}$$

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