Defense Special Weapons Agency
Alexandria, VA 22310-3398

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Operations
Nougat, Flintlock, Latchkey, Bowline, and Emery

Events
DES MOINES, TAPESTRY, AJAX,
CYPRESS and CAMPHOR

13 June 1962 – 5 December 1972

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United States Underground Nuclear Weapons Tests
Underground Nuclear Test Personnel Review

Prepared by Defense Special Weapons Agency

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13. ABSTRACT *(Maximum 200 words)*

This report is a personnel-oriented history of DoD participation in DOE underground nuclear weapons testing during Operations Nougat, Flintlock, Latchkey, Bowline, and Emery: Events DES MOINES, TAPESTRY, AJAX, CYPRESS, and CAMPHOR, 13 June 1962 – 5 December 1972. It is the eight in a series of historical reports which will discuss DoD underground nuclear test participation from 1962 forward. The other reports in this series cover DoD participa - tion in DoD events while this report discusses examples of DoD participation in DOE events. In addition to these historical reports, a restricted distribution report identifies all DoD and DoD affiliated participants, military, civilian, and DoD contractors, in both DoD and DOE events, and lists their individual dose data.

14. SUBJECT TERMS

Nevada Test Site (NTS	Emery		
Underground Tests (UGT)	Nougat	Bowline	AJAX
Defense Nuclear Agency (DNA)	Flintlock	CAMPHOR	CYPRESS
Centers for Disease Control (CDC)	Latchkey	DES MOINES	TAPESTRY
Underground Nuclear Test Personnel Review (UNTPR)			

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SUMMARY

Five selected Department of Energy (DOE)[1] underground nuclear tests, conducted from 13 June 1962 through 29 June 1971, are discussed in this report. Each of these events included DoD-sponsored experiments where DoD and DoD-contractor personnel may have received exposure to radiation as a result of their participation. These events were selected as examples of DoD participation in DOE events but do not cover all such participation. Three of the events, DES MOINES, TAPESTRY and AJAX were weapons-related tests, while CYPRESS and CAMPHOR were weapons-effects tests. Three were tunnel events while two were shaft events. The following table summarizes event data.

OPERATION	NOUGAT	FLINTLOCK	LATCHKEY	BOWLINE	EMERY
EVENT	DES MOINES	TAPESTRY	AJAX	CYPRESS	CAMPHOR
DATE	13 June 62	12 May 66	11 Nov 66	12 Feb 69	29 June 71
LOCAL TIME (hours)	1400 PDT	1237 PDT	0400 PST	0818 PST	1130 PDT
NTS LOCATION	U12j.01	U2an	U9al	U12g.09	U12g.10
TYPE	Tunnel	Shaft	Shaft	Tunnel	Tunnel
DEPTH (feet)	650	810	782	1,350	1,390
YIELD[2]	2.9 kt	Low	Low	Low	Low

[1] DOE's predecessors were the Atomic Energy Commission (AEC), 1 January 1947 to 19 January 1975; and the Energy Research and Development Administration (ERDA), 19 January 1975 to 1 October 1977.

[2] Low indicates less than 20 kilotons.

Releases of radioactive effluent were detected both onsite and offsite after the DES MOINES event. Releases of radioactive effluent were detected only within the confines of the NTS after the TAPESTRY, AJAX, AND CAMPHOR events. No release of radioactive effluent was detected onsite or offsite after the CYPRESS event.

As recorded on Area Access Registers, 15,234 individual entries to radiation exclusion (radex) areas were made after the above DOE events. Of this number, 259 were made by DoD-affiliated personnel (military, DoD civilian, and DoD contractor). The remainder were made by the DOE and other government-agency and contractor personnel.

The average gamma radiation exposure per entry for all participants was 21 milliroentgen (mR). The average gamma radiation exposure per entry for DoD-affiliated participants was 32 mR. The maximum exposure of a non-DoD participant during an entry was 1.5 R. The maximum exposure of a DoD-affiliated participant was 1.0 R. These maximum exposures occurred during the CAMPHOR and DES MOINES events, respectively.

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 U.S. Army's Manhattan Engineer District (MED) implemented the testing program in 1945. In 1947 its functions were assumed by the Armed Forces Special Weapons Project (AFSWP) and the Atomic Energy Commission that 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 24 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 four atmospheric tests in Nevada during July 1962, and the last U.S. atmospheric nuclear test was in the Pacific on 4 November 1962. The Limited Test Ban Treaty (LTBT), that 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, that resumed on 15 September 1961, continued on a year-round basis through the period of this report.

In 1977, 15 years after atmospheric testing stopped, the Center for Disease Control (CDC)[3] noted a possible leukemia cluster within the group of soldiers who were assigned to the Nevada Test Site during SMOKY event, one of the Nevada tests in the 1957 PLUMBBOB 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 nuclear testing. That study has progressed to the point where a number of reports describing DoD participation in atmospheric tests have been published by the Defense Nuclear Agency (DNA) as the Executive Agent for the DoD.

On 20 June 1979, the United States Senate Committee on Veterans Affairs began hearings on Veterans Claims for Disabilities from Nuclear Weapons Testing. In addition to requesting and receiving information on DoD personnel participation and radiation exposures during atmospheric testing, the Chairman of the Senate Committee expressed concern regarding exposures of DoD participants in DoD-sponsored and DOE-sponsored underground 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 reports similar to the program then under way on atmospheric testing data. This report is the eighth in a series regarding participation and radiation exposures of DoD military and civilian participants in underground nuclear events.

SERIES OF REPORTS.

Most reports in this series discuss DoD-sponsored underground tests in chronological order, after presenting introductory and

[3] The Center for Disease Control was part of the Department of Health, Education and Welfare (now the Department of Health and Human Services).

general information. The reports cover all underground tests identified as DoD-sponsored in Announced United States Nuclear Tests (DOE/NV-209), published each year by the DOE Nevada Operations Office, Office of External Affairs, except one category. This category of events not covered were nuclear test detection experiments in a program named VELA UNIFORM. Generally reentries after these tests were not performed, so significant exposure of participants to radiation did not occur.

This report discusses general participation of DoD personnel in DOE-sponsored[4] underground events, with specific information on those events which released radioactive effluent or where exposures of DoD personnel were involved.

A separate set of volumes (comprising one report) is a census of DoD personnel who participated in DOE and DoD underground nuclear tests and their radiation exposure data. Distribution of this volume is limited by provisions of the Privacy Act.

METHODS AND SOURCES USED TO PREPARE THE VOLUMES.

Information for these reports was obtained from several locations. Classified documents were researched at Headquarters, DNA, Washington, D.C. Additional documents were researched at Field Command/DNA, the Air Force Weapons Laboratory Technical Library, Sandia National Laboratories in Albuquerque, New Mexico, and Lawrence Livermore National Laboratory, Livermore, California. Most of the radiation measurement data were obtained at the DOE, Nevada Operations Office (DOE/NV), and its support contractor, Reynolds Electrical & Engineering Company, Inc. (REECo), both in Las Vegas, Nevada.

Unclassified records were used to document underground testing activities when possible, but, when necessary, unclassified information was extracted from classified documents. Both unclas-

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[4] For readability and ease of understanding, Sections 1 and 2 of this volume will use the acronym "DOE" to discuss the general responsibilities and procedures applicable to DOE and each of its predecessor agencies. Any activity that is tied to a specific time period will be discussed using the acronym of the agency in control during that period (i.e., safety experiments were conducted only during the era of the AEC).

sified and classified documents are cited in the References Section at the end of each report. Locations of the referenced documents also are shown. Copies of most of the unclassified references have been entered into the document collection 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 in hard copy or on microfilm at the REECo facilities adjacent to the CIC, or as original documents at the Federal Archives and Records Center, Laguna Niguel, California. The Master File of all available personnel exposure data for nuclear testing programs on the continent and in the Pacific from 1945 to the present is maintained by REECo for DoD and DOE.

Many source documents used to write other UNTPR reports were not available for the events described in this report. This lack of comprehensive reference material resulted in a somewhat less informative, though still accurate, reporting of these events.

ORGANIZATION OF THIS VOLUME.

A summary of this volume appears before this Preface and includes general objectives of the events, characteristics of each event, and data regarding DoD participants and their radiation exposures.

Section 1, "Introduction," following this Preface and the Table of Contents, discusses the historical background, underground testing objectives, DoD and DOE organizational responsibilities, and locations of NTS underground testing areas.

Section 2, "Underground Testing Procedures," explains the basic mechanics of underground testing, including containment problems and procedures, emplacement types, diagnostic techniques, the purpose of effects experiments, tunnel and drilling area access requirements, radiological safety procedures, telemetered measurements of radiation levels, and air support requirements.

A section on each event covered by this volume follows in chronological order. Each event section 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.

A reference list and appendices to the text, including a Glossary of Terms (Appendix A) and a list of Abbreviations and Acronyms (Appendix B), follow the event sections.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

FIGURES

Section Page

FIGURES (Continued)

FIGURES (Continued)

Section Page

TABLES

Section | Page

SECTION 1

INTRODUCTION

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

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 of 1 November 1958, a total of six safety experiments in shafts, five safety experiments in tunnels, and four weapons-related tests in tunnels were conducted by user laboratories. During this period, it was not the intent to achieve complete containment. Reduction of fallout and operational convenience were the prime motivations for underground testing. Thus, radioactive products from several of these tests were not completely contained underground. Containment of nuclear detonations was a new engineering challenge. Understanding and solving the majority of containment problems would require years of underground testing experience.

When the United States resumed testing on 15 September 1961, the first 32 on-continent tests were conducted underground, including a cratering experiment with the device emplaced 84 feet below the surface. Then the Dominic test series began in the Pacific, and the Sunbeam test series was conducted at NTS during 1962. These two series comprised the last atmospheric nuclear tests conducted 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 (LTBT) with the Soviet Union was signed on 5 August 1963. On 31 March 1976, the Soviet Union and the United States agreed to limit the maximum yield of underground tests to 150 kt. Currently, yields are reported as within a particular range; less than 20 kt, less than 150 kt, or 20 to 150 kt.

1.2 UNDERGROUND TESTING OBJECTIVES.

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

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

Nuclear weapons-effects tests (NWET) sponsored by DoD were conducted to determine the vulnerability or survivability of military systems or components when exposed to one or more effects of a nuclear detonation. The nuclear devices for these tests were provided by the DOE weapons-development laboratories and were designed to be similar to the nuclear components used in nuclear weapons. Actual weapon configurations were used in a few events. Military systems, structures, materials, electronics experiments, and other related experiments were provided by DoD and DOE agencies. Many of these tests were complex and involved greater numbers of participants than other categories of tests previously mentioned. Personnel from DNA, other government organizations, user laboratories and contractors, and DoD contractor agencies were involved.

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

DOE events DES MOINES, 13 June 1962; TAPESTRY, 12 May 1966; AJAX, 11 November 1966; CYPRESS, 12 February 1969; and CAMPHOR, 29 June 1971, conducted during Operations Nougat, Flintlock, Bowline, and Emery respectively, are discussed in this volume.

1.3 DOD TESTING ORGANIZATIONS AND RESPONSIBILITIES.

Administering the underground nuclear testing program was a joint DOE-DoD responsibility. The similar nature of the DOE and DoD organizational structure, during the period of this report, is shown in Figure 1-1.

1.3.1 Defense Nuclear Agency.

Headquarters of DNA is located near Washington, D.C., and is composed of personnel from each of the Armed Services and civilian DoD employees. It was originally established as the Armed Forces Special Weapons Project (AFSWP) to assume residual functions of the Manhattan Engineer District (MED). This action was initiated through issuance of a joint Army-Navy memorandum, dated 29 January 1947, which was retroactive to 1 January 1947 (when the Atomic Energy Commission was activated). The responsibility for DoD nuclear weapons-effects testing was assigned to AFSWP. The National Security Act of 1947 became law when the Secretary of Defense issued a memorandum on 21 October 1947 to the three Service Secretaries confirming the previous directive of 29 January, and thus, AFSWP officially represented all of the services. AFSWP was charged with providing nuclear weapons support to the Army, Navy, and Air Force. As originally chartered, AFSWP, was directly responsible to each of the three Service Chiefs. In 1951, the Air Force Special Weapons Center (AFSWC),

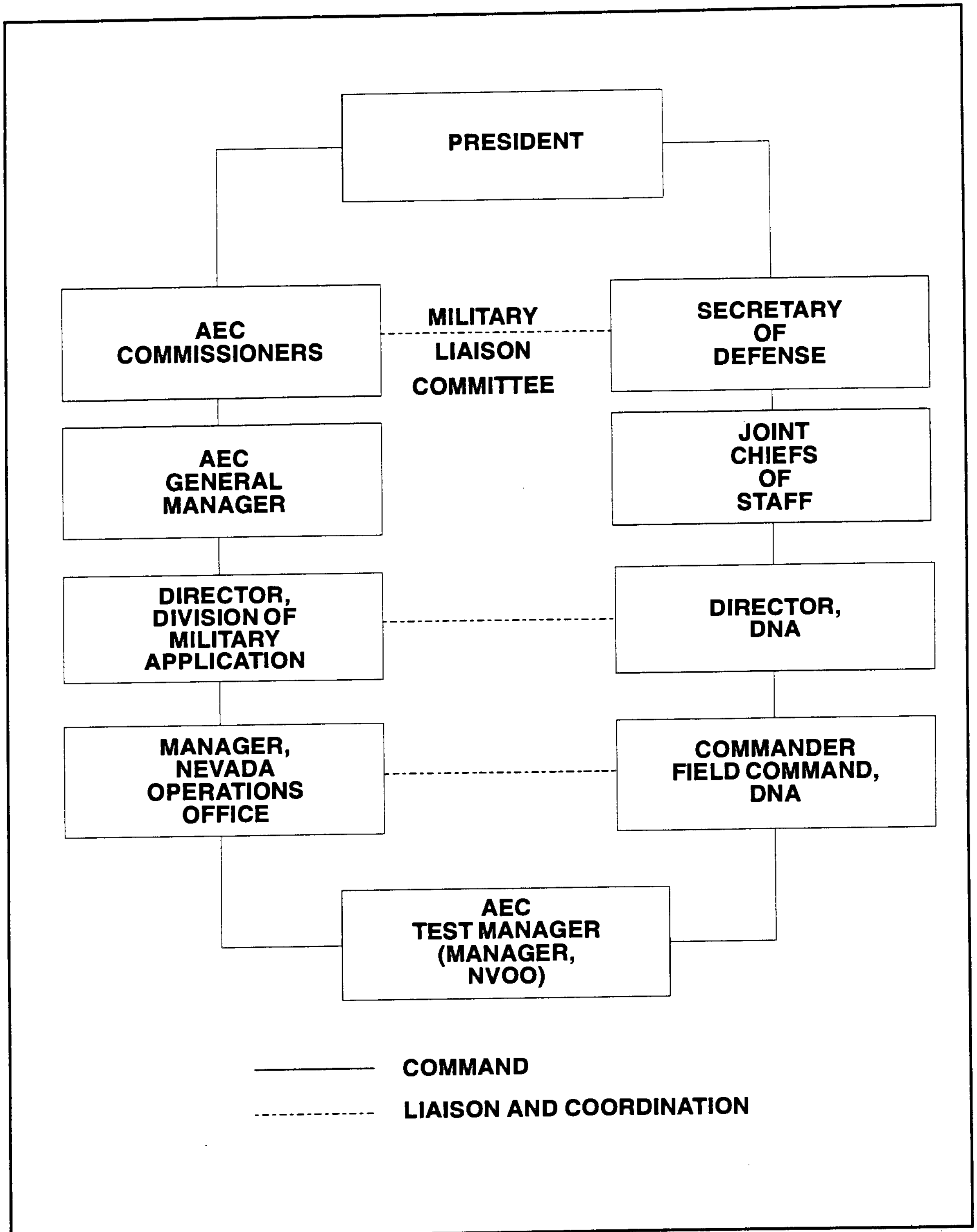

Figure 1-1. Federal government structure for continental nuclear tests (1971).

located at Kirtland Air Force Base (KAFB), Albuquerque, New Mexico, was assigned the responsibility by DoD of providing specific support to the AEC for continental nuclear testing (see Section 1.3.2). This command was not directly related to AFSWP; however, the two organizations coordinated several support tasks.

By issuance of General Order No. 2, Headquarters, DASA (HQ/DASA), dated 6 May 1959, AFSWP became DASA. Under its new charter, DASA was responsible to the Secretary of Defense through the Joint Chiefs of Staff (JCS).

DASA's five major areas of responsibility for the DoD included:

1. Staff assistance to the Office of the Secretary of Defense, through the JCS.

2. Research in weapons effects.

3. Atomic tests.

4. Weapons-related tests.

5. Assistance to the Services.

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

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

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

1.3.2 Air Force Support.

During the period of this report, the commander of AFSWC was requested to provided air support to the Nevada Test Site Organization (NTSO) during nuclear tests at the NTS. Direct support was provided by the Nuclear Test Directorate, the Special Projects Division, and the 4900th Air Base Group of AFSWC. The 4900th Air Base Group provided aircraft for shuttle service between KAFB, New Mexico, and Indian Springs Air Force Auxiliary Field (ISAFAF) in Nevada. The 4900th also provided aircraft and crews to perform low-altitude cloud tracking, radio relay support, and courier missions.

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

1. Elements of the 1211th Test Squadron (Sampling), Military Airlift Command, McClellan AFB, California, were detached

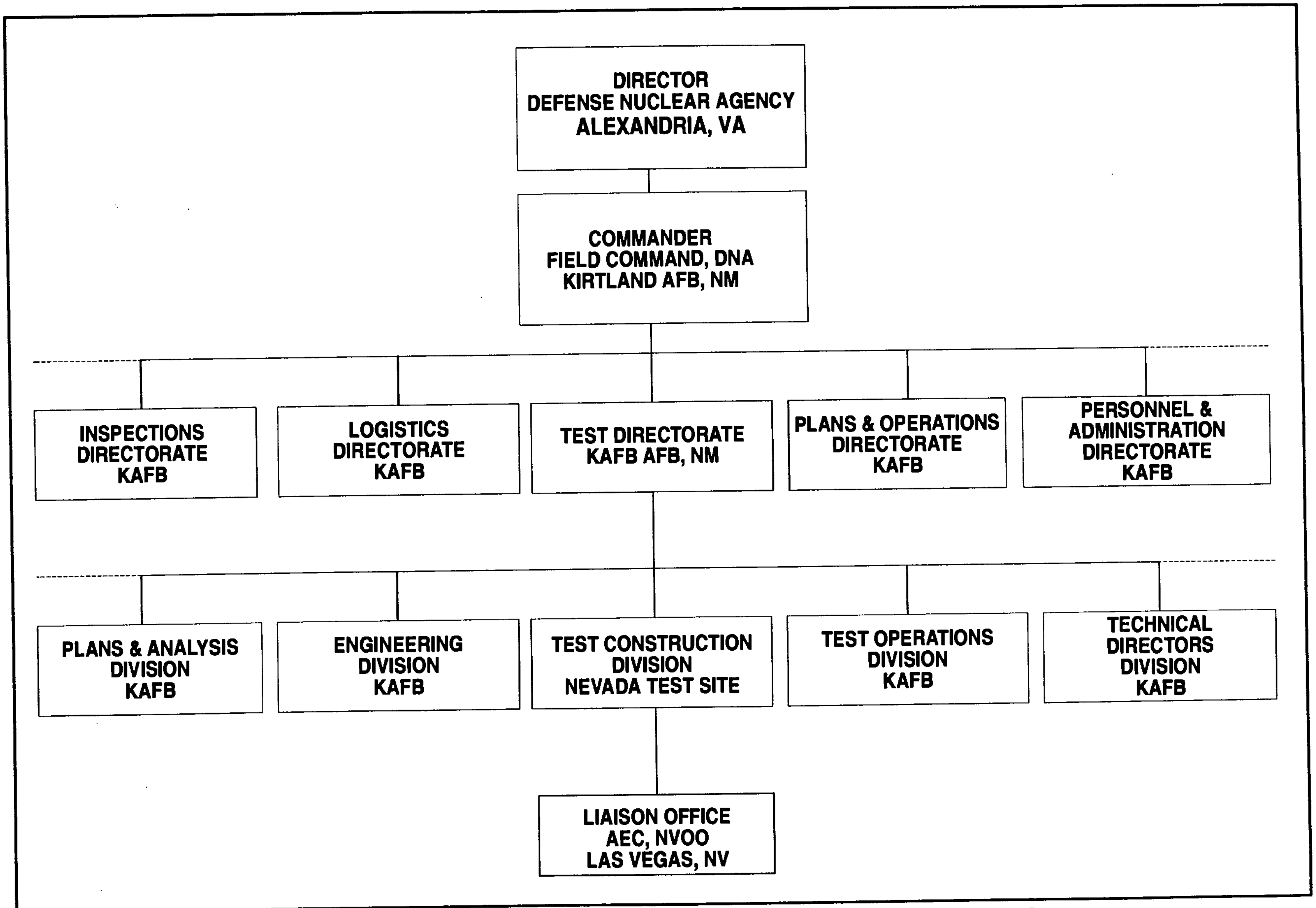

Figure 1-2. Partial organization chart of Field Command, Defense Nuclear Agency (1971).

to ISAFAF. Their primary task was cloud sampling. Personnel from this unit also assisted NTSO radiological safety personnel in providing support at ISAFAF, including decontamination of crews, equipment, and aircraft.

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

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

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

1.3.3 AEC-DoD Relationships.

DoD was responsible for establishing criteria for nuclear weapons, developing and producing delivery systems, developing nuclear weapons plans and forces, providing defense against nuclear attack, and obtaining nuclear weapons-effects data through DNA. DOE was responsible for research, development, production, and supply of nuclear weapons to the Armed Forces in quantities and types specified by the JCS. Quantities and types of weapons were described in the Nuclear Weapon Stockpile Memorandum, signed jointly by the Secretary of Defense and Secretary of Energy or his alternate and approved by the President. AEC, in association with DoD, was also responsible for providing field nuclear test facilities in the continental United States and islands in the Pacific.

The principal points of field coordination between AEC and DoD were at the Nevada Operations Office (NVOO) in Las Vegas and at NTS. From the beginning of the DoD underground nuclear weapons-effects test program (the first test was HARD HAT in February 1962) through the period covered by this volume, Field Command (or Test Command) was the fielding agency for DoD-DNA and served as primary point of contact with AEC/NVOO. AEC/NVOO and its predecessors represented AEC in the field for all Continental tests. The AEC nuclear weapons-development laboratories fielded underground tests as part of the weapons development program; DNA fielded underground tests at NTS to obtain weapons-effects data. Because the NTS was an AEC installation, the Manager, AEC/NVOO, was responsible for all operations there.

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

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

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

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

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

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

Under the supervision of the Test Group staff, experimenter personnel installed experiments and checked out instrumentation cables and recording systems. A series of electrical dry runs were conducted from the participating (user) laboratory control room and DNA monitor room at the Control Point (CP) complex (see Section 1.5) to determine that all signals and remotely-controlled equipment were functioning properly. After all systems were declared ready, permission was requested from the AEC to install the nuclear device. Installation and check out were conducted by the participating device-development laboratory with AEC security safeguarding the device and other classified materials. The next activities consisted of placing stemming materials in preplanned locations and checking all containment features.

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

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

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

1.4 AEC ORGANIZATIONS, CONTRACTORS, AND RESPONSIBILITIES.

1.4.1 Atomic Energy Commission.

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

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

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

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

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

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

1.4.2 Nevada Test Site Organization.

As stated in Chapter 0101 of the Nevada Test Site Organization Standard Operating Procedure (Appendix C, NTSO SOP Chapter 0101-01), the NTSO included AEC, DoD, user laboratory, contractor, agency, and organizational personnel who participated in or provided support for test operations at the NTS. The Manager, NV, headed the NTSO (See Figure 1-3.) The NTSO was a continuing

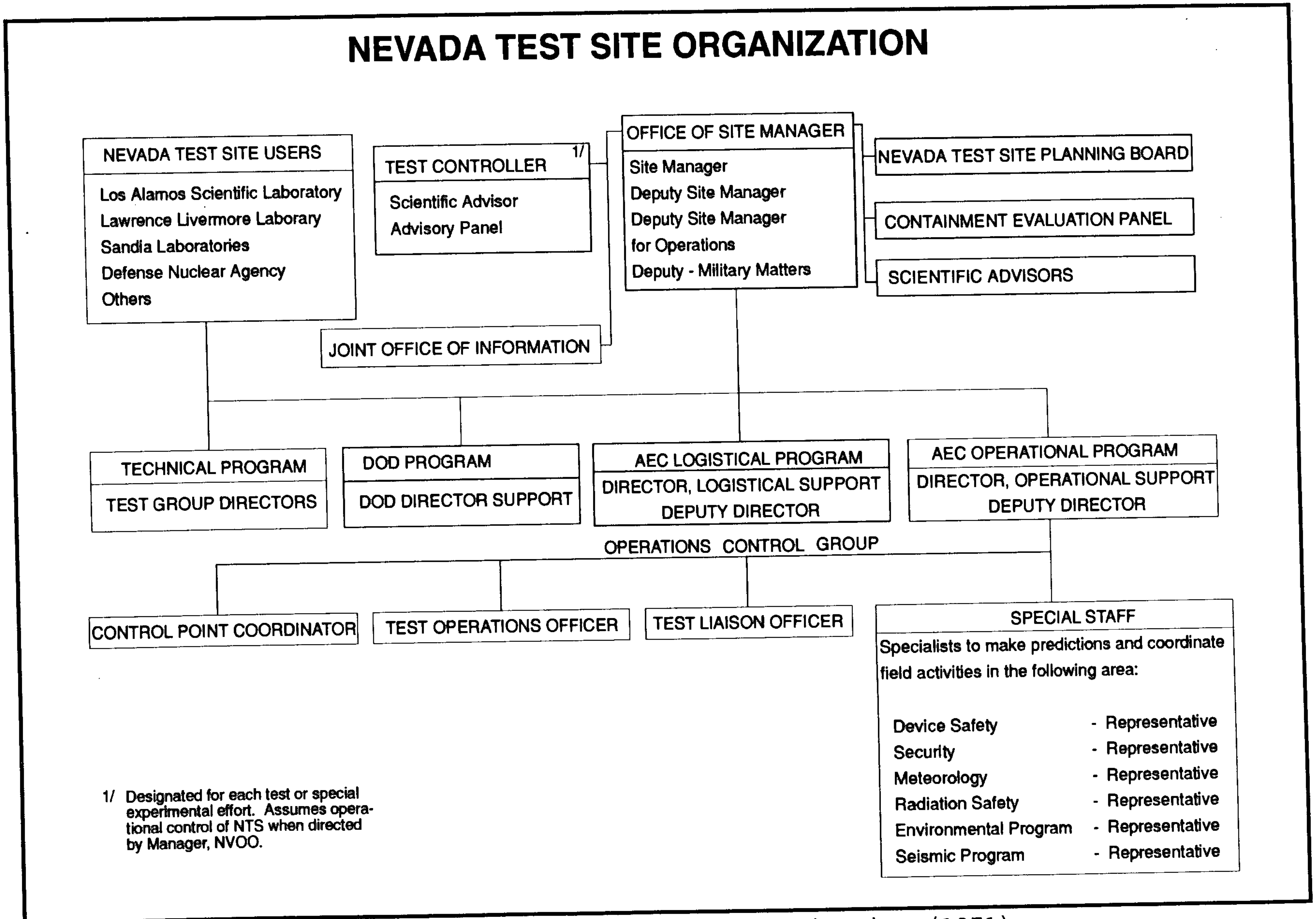

Figure 1-3. Nevada Test Site Organization (1971).

task organization whose composition could be readily changed in response to the needs and technical objectives of each test.

The Continental Test Organization (CTO)[5] was part of the original NTSO; however, it was disestablished on 1 August 1962 with its responsibilities (e.g., Military Deputy to the Manager, NVOO) being assumed by WETG, FC/DASA; Weapons Test Division (WTD)/DASA, TC/DASA, and subsequently by Test Directorate, FC/DNA. The Military Deputy to the Test Controller, as shown in Figure 1-3, was from Field Command and was responsible for coordinating DoD programs and support to NTSO.

1.4.3 NTSO Radiological Safety.

The Test Manager was responsible for protection of participating personnel and offsite populations from radiation hazards associated with activities conducted at NTS. By mutual agreement between the Test Manager and a scientific user (see Section 1.4.4), control of radiation safety within the area assigned for a particular activity was delegated to the user's Test Group Director during the period of time when such control could have had a direct bearing on the success or failure of the scientific program.

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

The U.S. Environmental Protection Agency (EPA)[6], was responsible to the Test Controller for operation of the offsite radiological safety program in accordance with procedures listed in Appendix D.

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[5] See DNA 6320F for further information.

[6] The U.S. EPA was established in 1971, and the Las Vegas Office of the Public Health Service (USPHS) became a part of the EPA.

1.4.4 NTS Scientific Users.

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

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

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

C. SL at Sandia Base (now KAFB), Albuquerque, New Mexico, was the AEC's other weapons laboratory. It was established in 1945 as Z Division of Los Alamos. In April 1948, it was named Sandia Laboratory, Branch of Los Alamos Scientific Laboratory; and in November 1949 it assumed its identity as a full-fledged weapons research institution operated by the Sandia Corporation (SC), a non-profit subsidiary of Western Electric. In May 1956 it was renamed Sandia Laboratory, Albuquerque (SLA) adding a Livermore Branch in March 1956 (to provide closer support to LLL); and ballistics test facilities operations at Tonopah Ballistics Range (now Tonopah Test Range), in September 1956. In 1969 the name was changed to Sandia Laboratories (SL). SL's role was to conceive, design, test, and develop the non-nuclear portions of atomic weapons and do other work in related fields.

1.4.5 Test Support Organizations.

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

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

Edgerton, Germeshausen & Grier, Inc., (renamed EG&G, Inc. in 1966) of Boston, Massachusetts, was the principal technical contractor, providing control point functions such as timing and firing, and diagnostic functions such as scientific photography and measurement of detonation characteristics. In addition, EG&G personnel manned the DoD monitor room. EG&G support facilities were maintained in Las Vegas and at NTS.

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

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

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

1.5 THE NEVADA TEST SITE.

An on-continent location was selected for conducting nuclear weapons tests; construction began at what was called the Nevada Test Site in December 1950, and testing began in January 1951. The name was changed to the Nevada Proving Ground (NPG) in March of 1952 and again changed to the Nevada Test Site on 31 December 1954.

The original boundaries were expanded as new testing areas and projects were added. Figure 1-4 shows the present NTS location bounded on three sides by the Nellis Air Force Range. NTS encompassed about 1,350 square miles in 1971. 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 resulted in a very low population density in the area around NTS.

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

Figure 1-5 shows the NTS, its various area designations, and the locations of the five events covered by this volume. In a location designation such as "U12n.07," the "U" signifies an under-

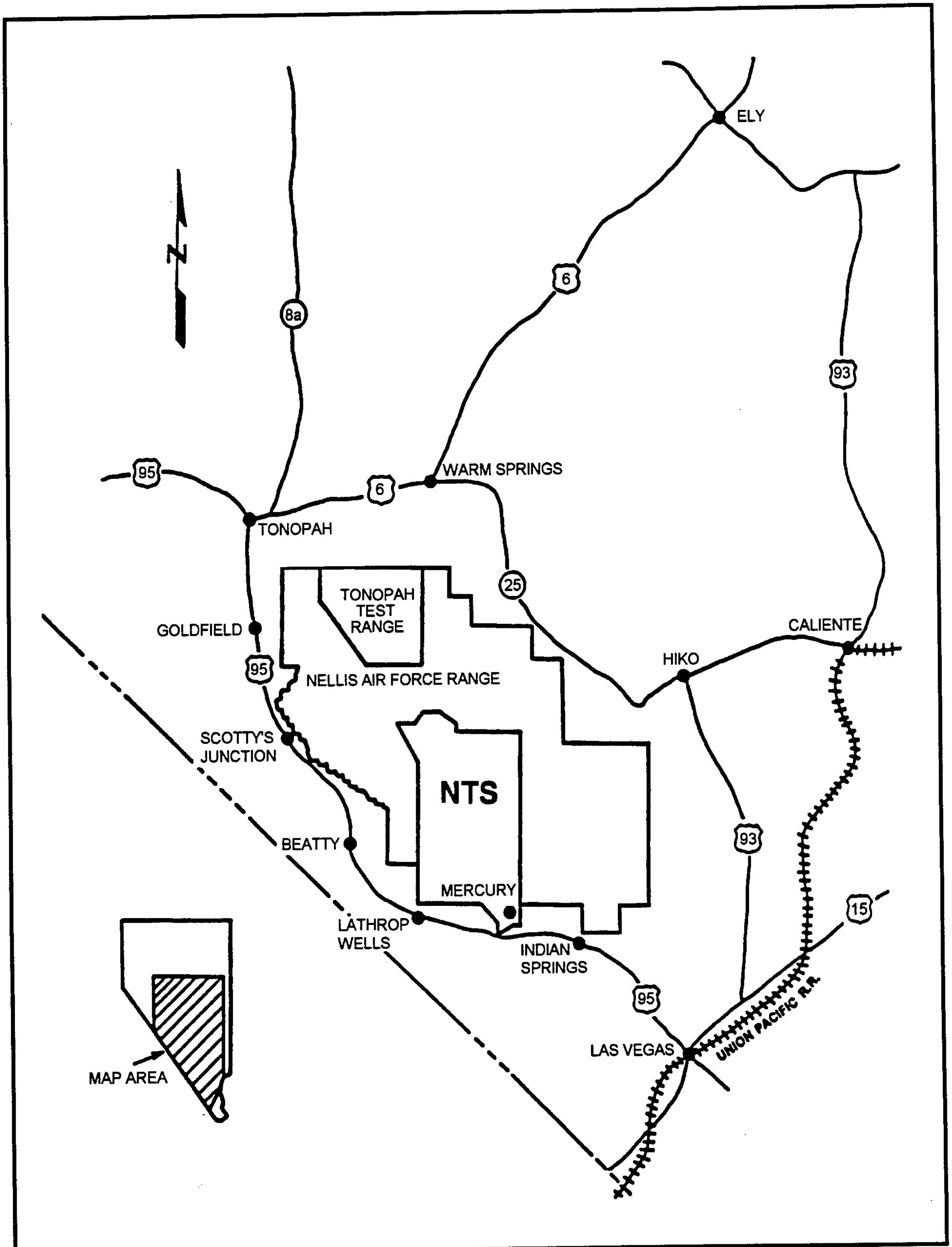


Figure 1-4. Nellis Air Force Range and NTS in Nevada.

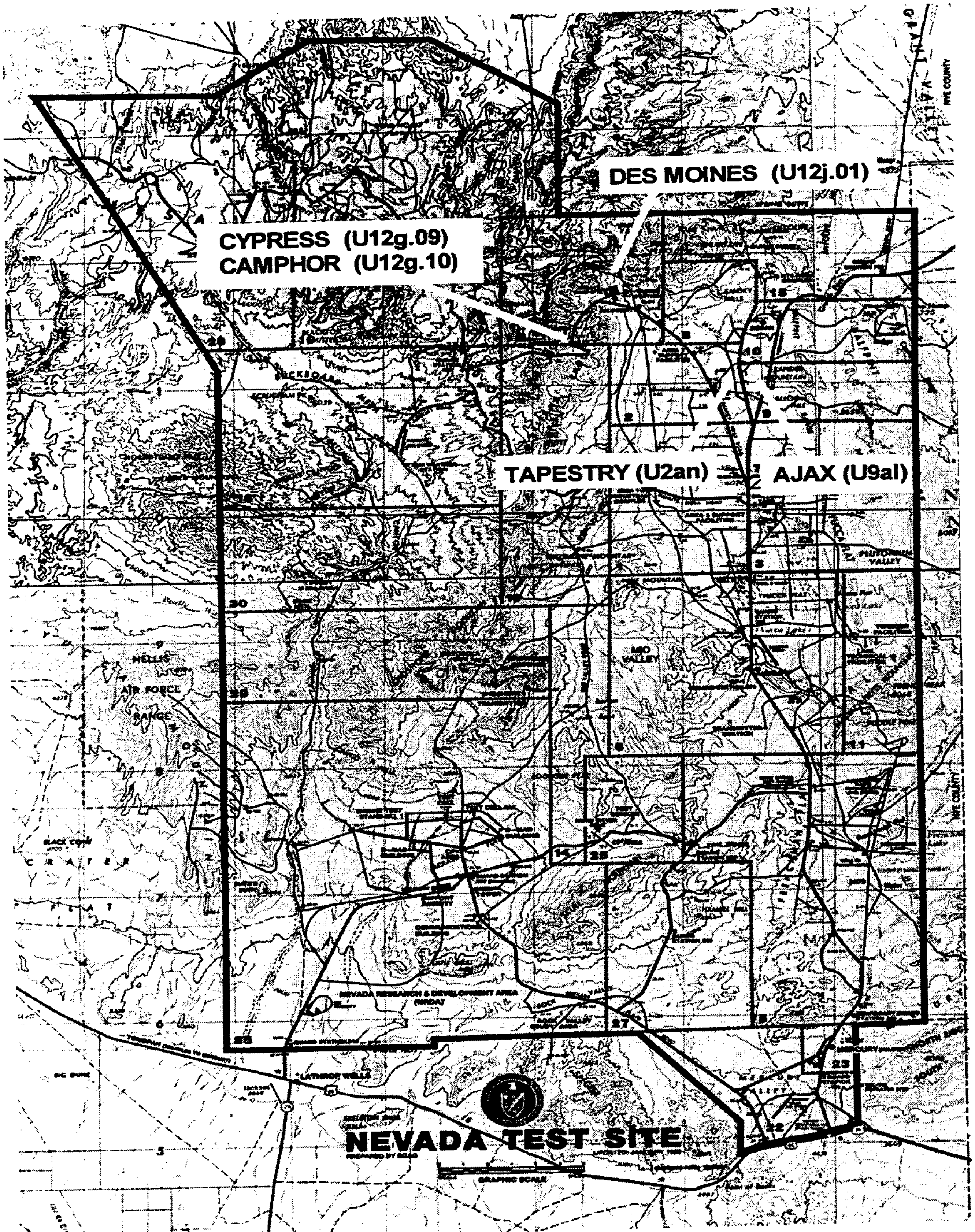


Figure 1-5. The Nevada Test Site.

ground location, "12" identifies the area at NTS, "n" denotes the tunnel, and "07" indicates the drift number. For shaft events, the letter designations after the NTS area identification denotes the test location within the area identified.

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

A mountain pass separates Frenchman Flat from Yucca Flat testing areas. The pass overlooks both Frenchman and Yucca Flats and contains the CP complex of buildings including Control Point 1 (CP-1) and Control Point 9 (CP-9) where timing and firing for most underground nuclear tests were performed, and Control Point 2 (CP-2) where radiological safety support was based.

Yucca Flat testing areas include Areas 1, 2, 3, 4, 7, 8, 9, and 10. Underground tests were conducted in 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. The top of the mesa is at an elevation of about 7,500 feet. All DoD tunnel emplacement events on NTS that were not in the Area 16 tunnel complex or the Area 15 shaft and tunnel complex were in Rainier Mesa and the adjoining Pahute Mesa. The major Rainier Mesa tunnel complexes were B, E, G, N, and T tunnels. Parts of T tunnel were constructed in the adjoining Pahute Mesa.

Area 15 is in the foothills at the north end of Yucca Flat. The deeper of the 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 DNA Report 6320F, _Operations Nougat and Whetstone_, while PILE DRIVER was discussed in DNA Report 6321F, _Operations Flintlock and Latchkey_.

Three of the DOE events discussed in this report were conducted in Area 12, one in Area 2, and one in Area 9.

SECTION 2

UNDERGROUND TESTING PROCEDURES

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

A primary consideration in all underground tests was the safety of test participants and the general public, especially regarding exposures to radioactive materials. This section discusses, in general terms, containment problems and procedures, types of emplacement, diagnostic techniques, effects experiments, area access requirements, industrial and radiological safety, radiation measuring systems, and air support requirements.

2.1 CONTAINMENT PROBLEMS AND PROCEDURES.

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

2.1.1 Vertical Shaft Containment.

Some of the first shaft 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, e.g., filling the shaft with aggregate and sand after device emplacement.

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

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

Some scientific and other cables from the device emplacement to the surface were another source of containment problems. While these cables could be embedded in concrete and epoxy, which helped prevent leakage along the outside of the cables, radioactive gases under high pressure could travel along the inside of cables. The inner conductors of high frequency coaxial cables were hollow copper tubes whose inner openings were an inch or more in diameter providing easy flow paths for gas. This problem was solved by using solid dielectric cables and factory-certified gas-tight cables and fittings. Another solution was to embed the inner components of these cables in epoxy or other materials at appropriate locations (such as in concrete plugs) in a technique known as gas blocking.

Many 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 in the presence of unsuitable geologic settings.

Another similar problem was the presence of higher-than-anticipated water content 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 the 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 the possibility of subsequent failure of geologic or constructed containment features.

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

2.1.2 Tunnel Containment.

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

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

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

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

Also, as tunnel testing continued, the Gas Seal Door (GSD) no longer was used as a containment device. It was replaced by strong concrete plugs 10 to 20 feet thick, referred to as Overburden Plugs (OBP). These plugs were keyed into the tunnel wall and were designed to withstand overpressures up to 1,000 psi and temperatures up to 1,000°F. Some of the plugs (constructed with a small access hatch) were penetrated by electrical cables and steel pipes. All of these penetrations were gas sealed (or capped) to provide protection against possible gas seepage through the plug.

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

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

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

2.1.3 Containment Evaluation Panel.

Because containment problems were particularly difficult to solve, the AEC began to change its emphasis on conditions under which nuclear detonations should be conducted. Another reason for the change of emphasis was that the LTBT required that radioactive fallout be confined within the borders of the sponsoring country.

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

On 19 March 1971, testing was suspended because a containment failure during BANEBERRY event caused serious venting. During this time, the TEP, under a formal charter, was changed to the Containment Evaluation Panel (CEP). The CEP, as an independent agent, evaluated the containment design of each nuclear test, assuring that all relevant data available for proper evaluation was considered. They were instructed to give increased emphasis to containment of radioactive materials. The panel membership was enlarged by the addition of a hydrologist, a geologist with expertise in underground nuclear phenomenology (both nominated by their respective organizations and approved by the Manager, NVOO), and consultants representing additional areas of expertise. These permanent advisors were representatives of the EPA, National Oceanic and Atmospheric Administration's Air Resources Laboratory (NOAA/ARL), and REECo. Each underground testing organization was represented as before.

Prior to a formal meeting of the CEP, each user planning a nuclear test prepared documents (i.e., a prospectus) describing its proposed tests with particular emphasis on containment considerations, and submitted these documents to each panel member for review. This information then was presented by the users to the CEP, generally at the following meeting. Details of the containment plan were reviewed and compared to previous successful experiences. Each CEP member (or alternate) was requested to submit a written statement describing the details considered favorable or unfavorable to achieve successful containment.

During the period covered by this report, evaluations to estimate the probability of successful containment conformed to specific guidance from the DMA at HQ/AEC. Each CEP member used this guidance to categorize each test as one of the following:

CATEGORY I

Underground nuclear tests which, on the basis of experience and judgment, will be contained satisfactorily.

CATEGORY II

Underground nuclear tests which are designed to be contained satisfactorily but which, in the judgment of the CEP, cannot be assigned to Category I because of location, configuration, or other factors. It is expected that experiments in this category will require special consideration and approval before being conducted.

CATEGORY III

Underground nuclear tests which are expected to release a significant amount of radioactive material. Experiments in this category will require special consideration and approval before being conducted.

A written report on each CEP meeting, containing the statement of each voting member and consultant, was forwarded to AEC/HQ for review and recommendations for approval to execute each event. The detonation authority request package also included the chairman's summary, the prospectus, and a transmittal letter with other pertinent event data, such as approval dates.

2.1.4 Test Manager's Advisory Panel.

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

This panel met at several readiness briefings in advance of each event and in the Control Room prior to and during execution of each event. The D-1 Containment Briefing provided a technical review of containment adequacy only, without considerations of cost, schedules, or test objectives. Panel members briefed the Test Manager's representative on aspects of test activities and meteorological conditions which he considered in his decision on whether a test should be conducted. Information presented by the panel included the status of test participants in the test area. Permission to arm and detonate the nuclear device was not given until all participants (other than those at approved manned stations) were clear of the controlled test area.

Weather conditions were considered in detail. Wind speeds and directions at increasing altitudes above ground were measured with weather balloons at stations around NTS, both preceding and during each test. Measurements were used to calculate and present information on where an unanticipated release of effluent might be transported off the NTS and what the levels of radiation might be in the predicted effluent cloud.

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

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

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

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

Conditions were considered favorable when (1) projected effluent direction was toward sparsely populated areas, (2) weather conditions were relatively stable, (3) EPA personnel could contact the few residents in the projected effluent direction and advise them of protective action to be taken, and (4) impact on milk supply from dairy cattle would be minimal. In addition, all essential equipment, personnel, and procedures were required to be in readiness status or had been activated before permission to arm and detonate was given.

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

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

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

2.1.5 Effluent Release Procedures.

If radioactive effluent was released from an underground event, established procedures were initiated in accordance with AEC NTSO SOP Chapter 0524, "Radiological Safety"; (see Appendix D). Immediately upon detection of possible venting and effluent release after a detonation, the following procedures were initiated:

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

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

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

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

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

Each of the above procedures was established to avoid or minimize exposure of the offsite population and maintain any such exposures below the radiation protection standards for individuals and population groups in uncontrolled areas, as established in AEC NTSO SOP Chapter 0524.

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

Some tunnel tests that did not result in venting of radioactive effluent to the atmosphere did have a failure of the containment system within the tunnel. High radiation levels existed in locations where reentry personnel needed to enter to accomplish data recovery. Procedures developed to minimize exposures of reentry and recovery personnel included the placement of remote radiation detectors at strategic tunnel complex locations and the use of tunnel atmospheric samplers that pulled air (for radiochemical and toxicological analyses) from the ventline prior to air filtering.

Remote monitoring and sampling equipment provided information on radiation levels, toxic gases, and explosive mixtures necessary to determine whether tunnel ventilation should be accomplished before reentry. Tunnel ventilation filters stopped particulate radioactivity and activated charcoal in the filters absorbed most of the radioiodines, thus allowing primarily only radionuclides of the noble gases, such as xenon, to be released to the atmosphere. (Exposure to radionuclides of the noble gases is far less hazardous than exposure to other fission products.) Release of this radioactive material to the atmosphere in a gradual, highly-controlled manner (initiated during tunnel ventilation in order to protect onsite personnel) was subject to approval by the Test Manager.

2.2 EMPLACEMENT TYPES.

The AEC conducted 365 tests during the period covered by this report. Five of those tests were considered to have sufficient DoD participation and chance for exposure to be included in this series of UNTPR reports. Table 2-1 lists the five events and pertinent data. Of these five events, two were shaft and three were tunnel emplacement events. Both tunnel and shaft emplacement types are discussed in this section. An emplacement type not discussed in this report was one that resulted in the excavating or ejecting of material from the ground surface to form a crater (see Crater Experiment in the Glossary of Terms). A DoD cratering event, DANNY BOY, was conducted in 1962 during Operation Nougat (see DNA 6320F).

2.2.1 Vertical Shaft Emplacement.

A vertical shaft nuclear detonation was intended to be contained 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 calculated to contain the explosion. At detonation time, a cavity was formed by vaporized and melted rock. Pressure from the hot gases in the cavity held surrounding broken rock in place until the cavity area cooled sufficiently to decrease pressure. As broken rock fell into the cavity formed by the detonation, a chimney was formed. If the chimney of falling rock reached the surface, a subsidence crater was formed. Figure 2-1 shows a typical subsidence crater.

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

Table 2-1. AEC events - 13 June 1962 through 29 June 1971.

OPERATION	NOUGAT	FLINTLOCK	LATCHKEY	BOWLINE	EMERY
EVENT	**DES MOINES**	**TAPESTRY**	**AJAX**	**CYPRESS**	**CAMPHOR**
DATE	13 JUNE 62	12 MAY 66	11 NOV 66	12 FEB 69	29 JUNE 71
LOCAL TIME (hours)	1400 PDT	1237 PDT	0400 PST	0818 PST	1130 PDT
NTS LOCATION	U12j.01	U2an	U9al	U12g.09	U12g.10
TYPE	Tunnel	Shaft	Shaft	Tunnel	Tunnel
DEPTH (feet)	650	810	782	1,350	1,390
YIELD[7]	2.9 kt	Low	Low	Low	Low

[7] Low indicates less than 20 kilotons.

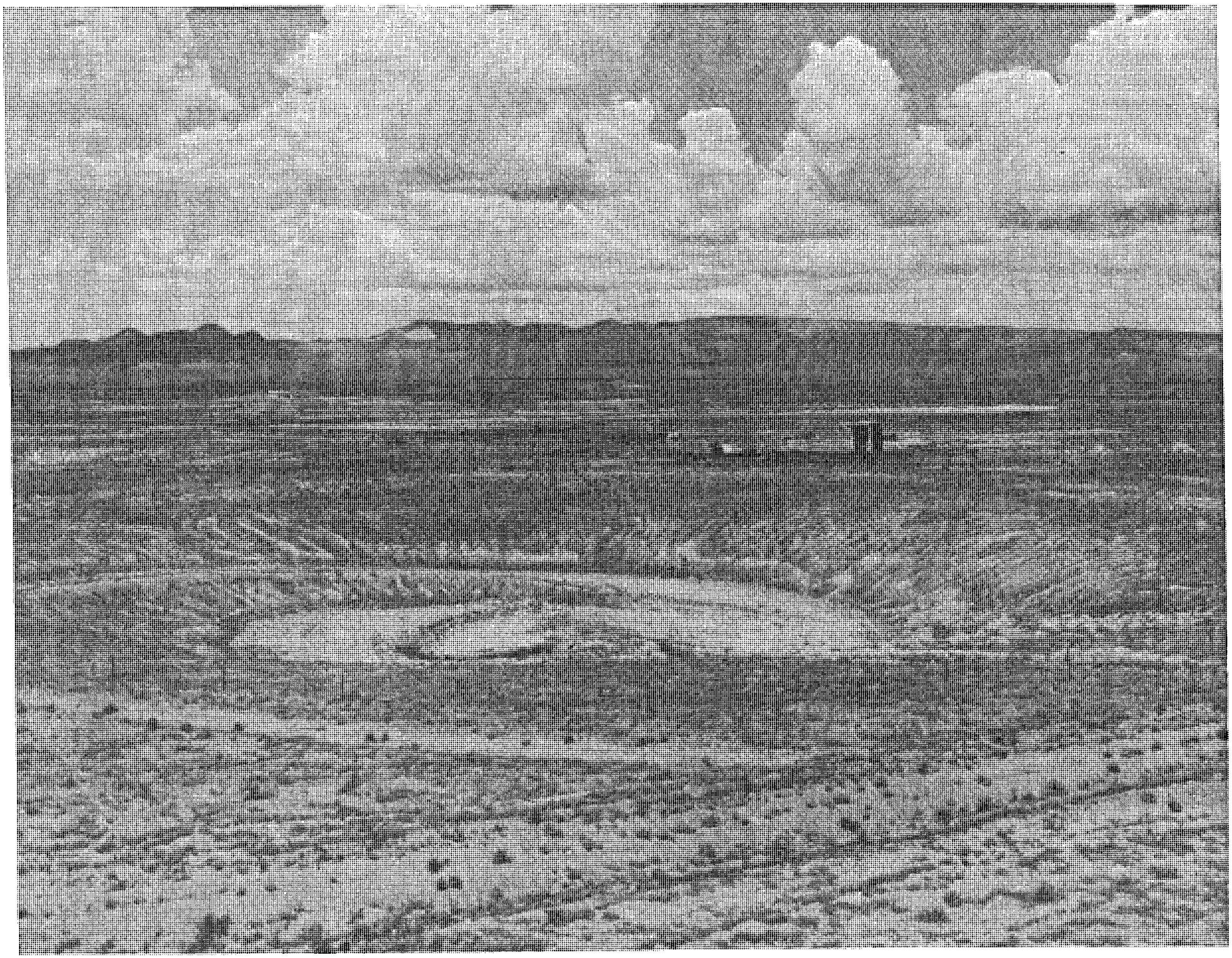


Figure 2-1. A typical subsidence crater.

ally significantly larger than the expected yield. However, the minimum depth of burial was 600 feet.

Both TAPESTRY and AJAX events, discussed in this report, and most other vertical shaft underground tests conducted by DoD included a vertical line-of-sight (VLOS) pipe system to the surface and a mobile tower on the surface that contained the weapons-effects experiments (see Figure 2-2). The VLOS pipe system contained several mechanical closures designed to prevent the release of radioactivity into the atmosphere. These closures were open at the time of detonation but closed within milliseconds to stop the flow of material up the pipe. The open volume between the VLOS pipe and the wall of the drill hole was filled with sand and other materials. One or more non-porous material plugs were placed around the pipe. Electrical cables that went downhole were gas blocked to prevent gas seepage to the surface. Effects experiments were contained in a mobile tower on the surface that was moved away from the hole after device detonation but before surface collapse (formation of the subsidence crater). One problem was the possibility of seepage after surface collapse if some pathway to the surface developed. Some radioactive effluent was released into the atmosphere during several VLOS DoD tests.

2.2.2 Tunnel Emplacement.

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

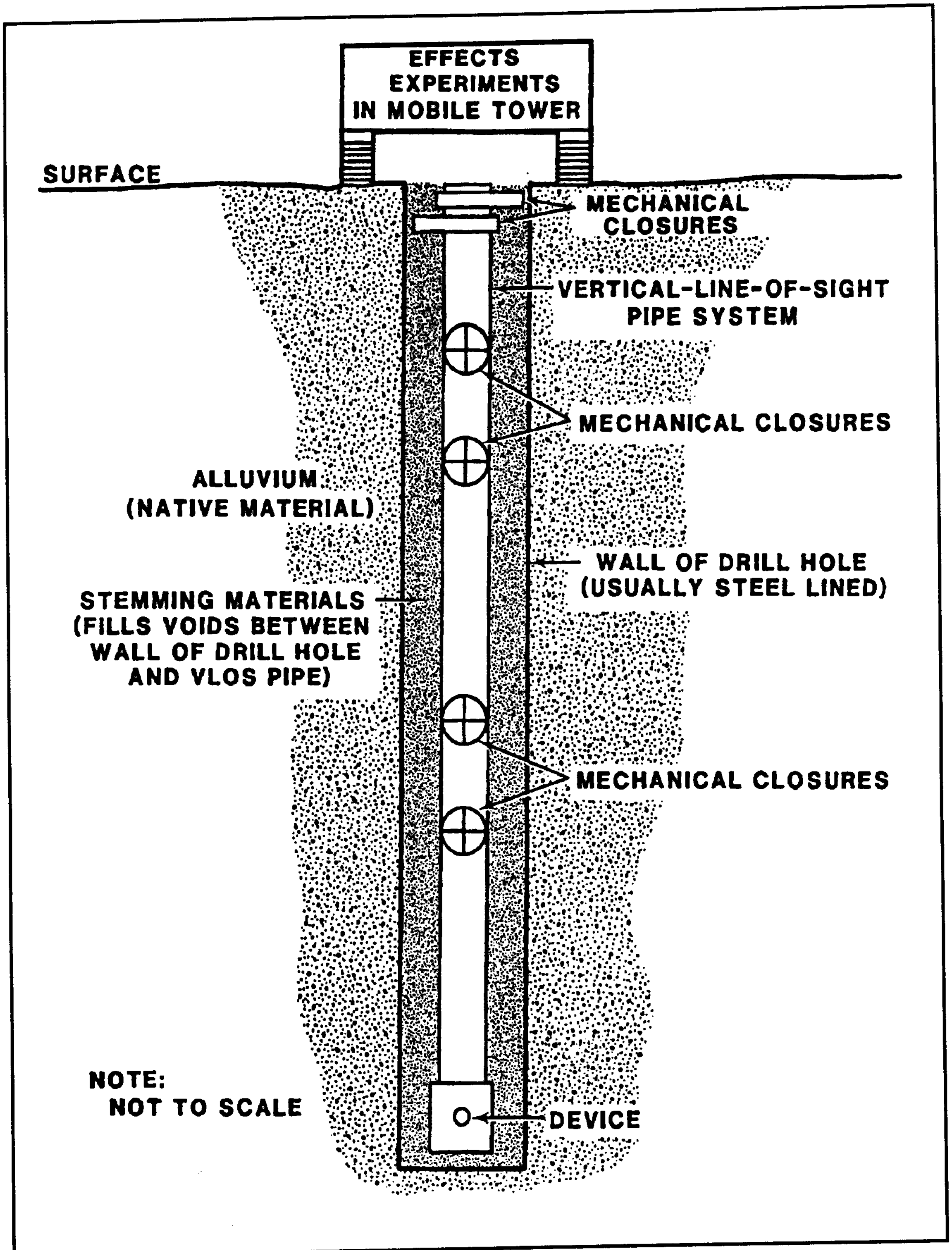


Figure 2-2. Vertical LOS pipe configuration.

Each of the tunnel events discussed in this report included HLOS pipe systems placed in horizontal drifts in tunnel complexes (see Figure 2-3). Each device was placed close to the end of a drift inside a tunnel complex. An HLOS pipe system (some over 1,000 feet long), including several mechanical closures and one or more test chambers (which contained effects experiments), were installed in the drift. The mined area surrounding the HLOS pipe was filled (stemmed) with various mixtures of grout to a distance of several hundred feet from the device location. This closure of the HLOS pipe in the stemmed area was the primary containment system. Ground shock and expansion of the gaseous cavity material exerted pressure on the tunnel walls and stemming materials to form a stemming plug, closing the tunnel and HLOS pipe immediately after detonation. All electrical cables and other penetrations within the stemmed area were gas blocked carefully to prevent or minimize seepage of radioactive gases through the stemming plug. The mechanical closures in the HLOS pipe were designed primarily to protect the effects experiments. However, they also had some effect on the formation of the stemming plug. The secondary (or backup) containment system included two or more concrete plugs, which were strategically keyed into the tunnel walls to prevent leakage of radioactive gases outside the tunnel should the primary system fail. These concrete plugs were designed to withstand the maximum expected pressure and temperature.

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

2.3 DIAGNOSTIC TECHNIQUES.

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

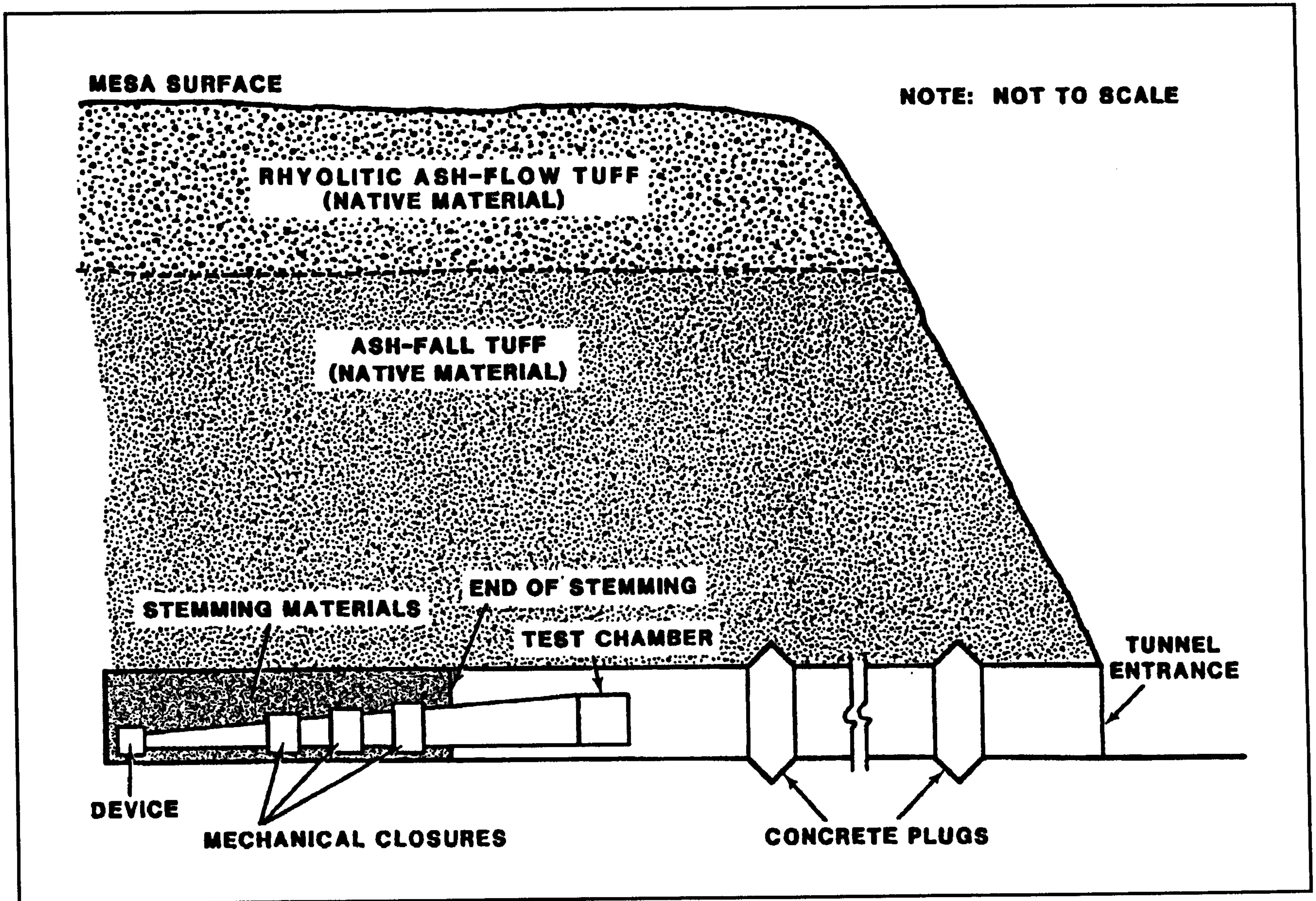


Figure 2-3. Horizontal LOS pipe configuration.

2.3.1 Radiation Measurements.

Measurements of radiation from an underground detonation were made possible by the development of a system of remote detectors and cabling that sent signals to recording facilities located at 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 billionths of a second after a detonation, before the detectors were destroyed. These measurement systems required the most advanced electronic technology available. Considerable research and development were necessary to acquire and refine these capabilities.

2.3.2 Radiochemical Measurements.

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

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

A major radiochemistry sampling method which continued in use for shaft and tunnel detonations was postevent core drilling. This drilling technique was used to obtain samples of solidified radioactive debris which had collected in a molten pool at the bottom of the cavity that was formed by the detonation and cavity gas. This requirement resulted in the development of precise directional drilling techniques and several advancements in the science of core drilling and radiochemical analysis.

2.4 EFFECTS EXPERIMENTS.

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

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

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

2.5 TUNNEL AND DRILLING AREA ACCESS REQUIREMENTS.

Access to underground work and drilling sites was controlled for a number of reasons. During construction, safety of both workers and visitors in these locations could have been jeopardized by carelessness or seemingly harmless activities of untrained and uncontrolled workers or visitors. When security-classified materials were in these locations, only personnel with appropriate security clearances were permitted access to the area. The presence, or anticipated presence, of radioactive material in a location 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 an event in a tunnel or other underground work site, the tunnel Superintendent was responsible to the REECo Project Manager for safety of personnel underground. From 1962 forward, Radsafe and tunnel logbooks usually were used to record names and radiation exposure information for only those persons entering a tunnel during postevent reentry and recovery operations. In the early 1970s, as a result of the Mine Safety and Health Act, tunnel logbooks were expanded to list all persons entering the tunnels (i.e., visitor, mining, drilling, Radsafe, etc.). Visitors and other personnel, who were not assigned to work in the tunnel, obtained permission for entry from the Superintendent or his representative. They were apprised of tunnel conditions and safety regulations and were listed in the logbooks. In the event of an accident or other emergency condition underground, the logbook provided information on numbers of personnel and their locations.

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

After detonation, aerial damage surveys to determine the accessibility of the various recovery stations were required before surface reentry operations were begun. When the reentry teams were given permission to depart Gate 300 (a check point set up in Area 3, just north of the turnoff to the CP, also known as Guard Station 300; see Figure 1-5) by the Test Manager, radiation and industrial hygiene surveys were conducted on the mesa and in the portal areas before any other personnel were allowed in these areas.

Before underground recovery operations were begun, a listing was made of hazardous elements whose performance degradation; functional failure; or physical, chemical, or electrical properties constituted a posttest hazard within the test system complex. General requirements and standards governing safety were based on pertinent DNA safety instruction. Hazardous elements were defined to include active experiments and/or hardware containing radioactive, explosive, fire hazard, pressure vessel, evacuated container, electrical, toxic, and/or chemically hazardous components.

Instructions on the proper procedure, should a potential hazard have become a real hazard as a result of detonation, were made available to the underground reentry team and recovery personnel. Situations where permission was to be given before the tunnel reentry team would be allowed to proceed (including checking pressure and sampling gas on the working point [WP] side of the GSP, opening the OBP manway doors, and removing the insulation materials from inside the OBP crawl spaces) were outlined in detail prior to reentry. Permission to proceed was given by a responsible party outside the tunnel complex on the basis of information transmitted by the reentry team. The required condition of the tunnel before experimenter personnel were allowed access to the test chambers was also outlined specifically.

Before experiments were released to the experimenters, each experiment was monitored for radioactivity and bagged to reduce spread of contamination inside the tunnel. Swipe samples were taken on experiments and equipment leaving the tunnel area to verify that contamination standards were not exceeded. Experiments and equipment with higher-than-allowed removable contamination levels were taken to the Test Support Compound, that was equipped to disassemble radioactive/contaminated materials. Shipment from the Test Support Compound was restricted to organizations that were licensed to handle and store radioactive materials.

Control of tunnel access reverted to tunnel management personnel after tunnel reentry and recoveries. Entry procedures and use of the tunnel logbook were then implemented as discussed previously.

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

All persons entering radex areas were logged on an "Area Access Register" form. Names and organizations represented were listed. Radiation exposures from reports for the year and quarter were listed upon entry. (The use of previous radiation exposure data was to assure that personnel approaching current radiation exposure guide limits would not be allowed to enter radex areas when they could potentially accumulate exposures above those levels.) Self-reading pocket dosimeter measurements were entered on the Area Access Register upon exit.

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

2.5.2 Drilling Area Access Control.

Access to drilling areas was controlled by the drilling superintendent and the AEC Test Group Director for the same reasons as access to underground workings was controlled. While drilling 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 the purpose of each visit were entered in the daily drilling report, and it was assured that visitors wore hard hats and understood safety regulations.

The laboratory that provided the device controlled access to the area, assisted by security force personnel, when classified materials (including the nuclear device) were brought into the area for emplacement. After the event, when the drill site was a radex area, during classified material removal or postevent drilling, both security and radiological safety access controls were in effect as discussed under "Tunnel Access Control" paragraph 2.5.1 above).

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 the potential for encountering toxic gases, explosive mixtures, and radioactivity.

Miles of underground workings were constructed at several locations. More depth of vertical 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.

The lost-time accident frequency, however, 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.

Safety was a joint effort by AEC, DNA, and their predecessors, and by the many other government agencies and contractors at NTS. Administered by REECo, the safety program enjoined all NTS personnel to conduct operations safely, and was exemplified by signs at the portal of a typical DoD tunnel complex as shown in Figure 2-4, one of which states, "Safety With Production is our Goal."

The safety procedures for all NTS operations are voluminous and cannot be included in this report. Appendix E of this volume (General Tunnel Reentry Procedures for Department of Defense and Sandia Laboratory Nuclear Tests, April 1968, published by Sandia Laboratory) is an example of a pertinent safety procedure. As this procedure indicates, several aspects of industrial safety are interrelated. Information on monitoring levels of radioactivity and personnel exposures to radiation is presented in Section 2.7, "Radiological Safety Procedures."

Monitoring of toxic gases and checks for explosive mixture were an important aspect of safety in underground workings, on drill rigs, and in drillhole cellars (the enlarged excavated area un-

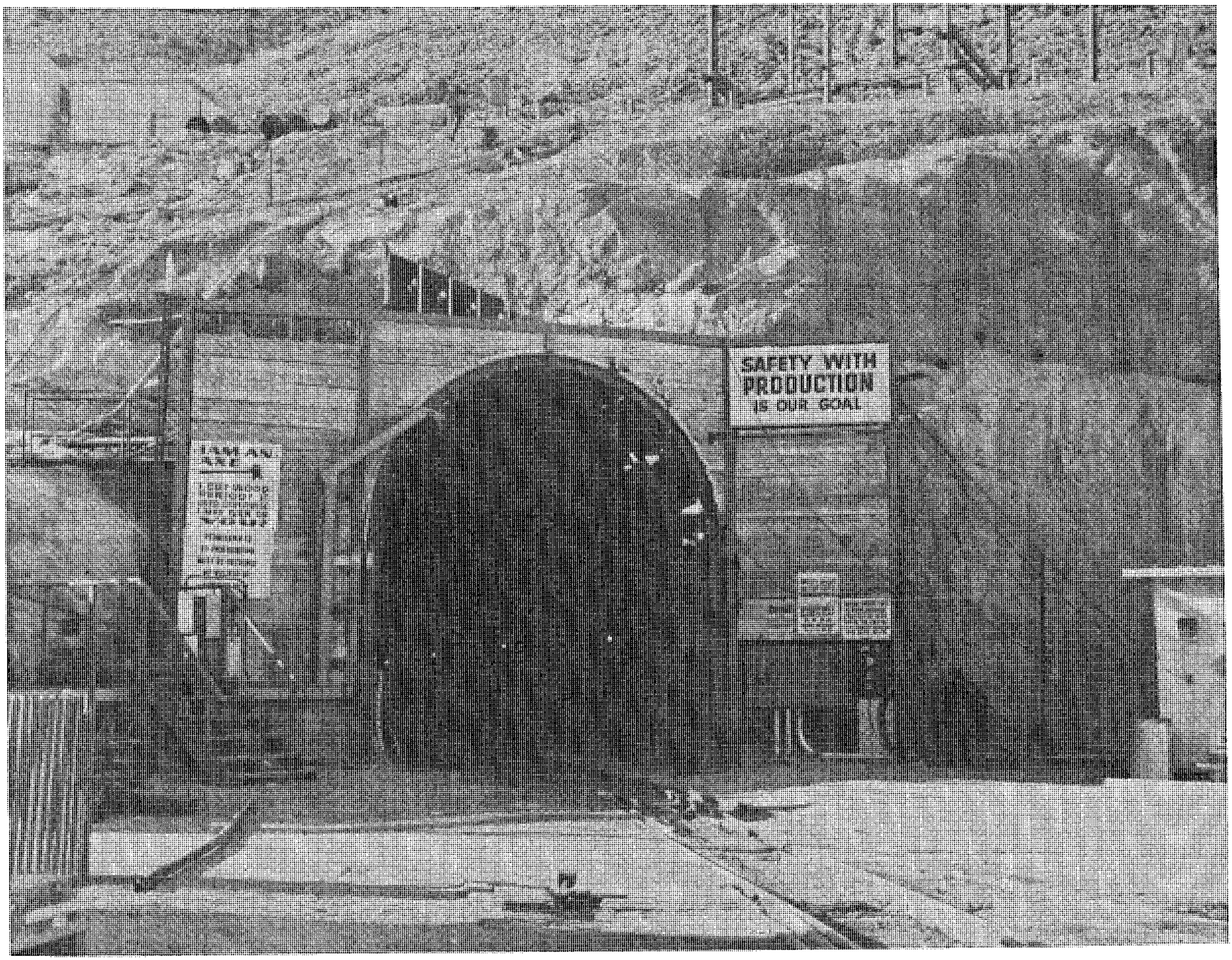


Figure 2-4. Portal of a typical DoD tunnel complex.

der the drill rig platform used for valving and other equipment). Toxic gases and explosive mixtures were created by both the nuclear detonations and mining and drilling operations. The Draeger multi-gas detector and MSA explosimeter were available to detect such gases. The Fyrite or J&W oxygen indicator also was available to determine the oxygen content of the working atmosphere. The GPK was a combination oxygen indicator and explosimeter and was the instrument most commonly used by tunnel monitoring personnel throughout the period covered by this report. Requirements were that tunnel and drill rig breathing atmosphere contain at least 19.5 percent oxygen. During the period covered by this report, it was required that the breathing atmosphere contain less than the levels of toxic gases and percentage of the lower explosive limit (LEL) listed below. Explosimeter instruments are calibrated with 5.6 percent methane (adjusted for atmospheric temperature and pressure) in air as 100 percent of the LEL for methane mixtures with air. Less than 100 percent of the LEL is not an explosive mixture of gas or gases.

Gases	**Maximum Concentration**
Carbon monoxide, CO	50 ppm
Carbon dioxide, CO_2	5,000 ppm
Nitric oxide plus nitrogen dioxide, NO + NO_2	25 ppm
Nitrogen dioxide, NO_2	5 ppm
Explosive mixtures	10% of the LEL

Procedures for controlling percentages of the LEL and toxic gases after each event are discussed in the event sections (Sections 3 through 7) as appropriate.

2.7 RADIOLOGICAL SAFETY PROCEDURES.

Procedures were developed in an effort to evaluate radiological, toxic, and other hazards and to protect workers and the public from unnecessary exposures. The following were the primary written procedures and implementation methods used at the NTS from 1962 through 1971.

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

Chapter 0524, Radiological Safety, of this procedure (which appears as Appendix D to this volume) defined responsibility and established criteria and general procedures for radiological safety associated with NTS programs. Some of the major areas discussed are: film badge procedures, radiation surveys, entry into controlled areas, and radiation exposure guides. Roles of the onsite REECo Environmental Sciences Department and the offsite United States EPA are also defined in NTSO SOP Chapter 0524.

2.7.2 The Standard Operating Procedures for the Environmental Sciences Department, REECo.

These SOPs were reviewed and/or updated annually to address, in more detail, the radiological safety aspects discussed in the latest revision of NTSO SOP Chapter 0524.

2.7.3 Implementation of Radiological Procedures.

During the period of this report, which covers the time frames of DNA 6320F, 6321F, 6322F, and 6323F, numerous types of monitoring equipment were used. All the required equipment, devices, and capabilities for monitoring radiation levels in the environment and monitoring external and internal exposures of personnel used during this period are described as follows:

A. Portable Radiation Detection Equipment.

- Eberline PAC-3G (alpha)
- Eberline PAC-4G (alpha)
- Eberline PAC-1SA (alpha)
- Eberline E-500B Survey Meter (beta and gamma)
- Jordan AGB-500B-SR Radector (gamma)
- Jordan AGB-10K-SR Radgun (gamma)
- Technical Associates and Hanford Cutie Pie Survey Meter (beta and gamma)
- Eberline PNC-1 (neutron)
- Eberline Model E-112B (low range beta and gamma)
- Technical Associates Juno Survey Meter (alpha, beta, and gamma)

- Technical Associates Juno SR-3 (medium range alpha, beta, and gamma)
- Technical Associates Juno SRJ-7 (medium range alpha, beta, and gamma)
- Technical Associates Juno HRG-7 (high range gamma)
- Teletector Model 6112 (high range beta and gamma)
- Standard SS-2 (tritium)
- Bendix T-290 (tritium)
- Precision Model P-111 Scintillator (gamma)
- Floor Monitor (alpha)
- Floor Monitor (low range beta and gamma)
- Portable Monitors (low range beta and gamma)
- Victoreen Radector AGB-500B SR (high range gamma)
- Gateway Monitor (gamma alarm)
- FN-la (fast neutron)
- Beckman MX-5 (low range beta and gamma)
- Nuclear-Chicago 2715 Nemo (neutron)

B. Air Sampling Equipment.

- Model 102 semi-portable sampler
- Satellite sampler
- Hurricane high-volume portable sampler (Gelman)
- Vacuum pump low-volume portable sampler (Gelman)
- Portable gasoline-driven air sampling units (Model 102, REECo-designed)
- Continuous and sequential samplers
- Fallout and resuspension trays

C. Laboratory Analysis Capability.

The Environmental 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 for specific gamma-emitting radionuclides. The laboratory also analyzed some of the above-mentioned samples for nonradioactive materials, such as beryllium, through use of an emission spectrograph and by wet chemistry procedures. A spectrophotometer was used to analyze for other materials.

D. Monitoring of Personnel Exposures.

A DuPont-type 301-4 film packet with a type 508 low-range component and a type 834 high-range component was used as the personnel dosimeter of record in 1962, the initial testing period discussed in this volume. Ranges of these two components were 30 mR to 10 R, and 10 R to 1,000 R, respectively. The packet was wrapped with a 28-mil-thick lead strip covering an area one-half by one inch on each side. The packet was contained in a plastic bag with the colored tape across the top of the bag indicating validity for a given month. The bag was clipped to the security badge, and security guards ensured that all personnel entering the NTS wore a valid film dosimeter.

The NTS combination personnel dosimeter and security credential holder was placed in use in 1966 to provide the increased personnel dosimetry capability necessary to meet the radiation exposure problems associated with nuclear rocket testing and underground nuclear detonations. The holder was designed to accommodate a DuPont-type 556 film packet, a fast neutron packet (containing Kodak NTA film), an identification plate, criticality accident components, the security credential, and a snap-type clip. The complete package 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 NTS combination personnel dosimeter and security credential holder is shown in Figure 2-5. In March 1971, with the discontinuance of the DuPont film, NTS dosimetry operations converted to the Kodak Type III film. This film packet contained two component films, one low range and one high range. Gamma

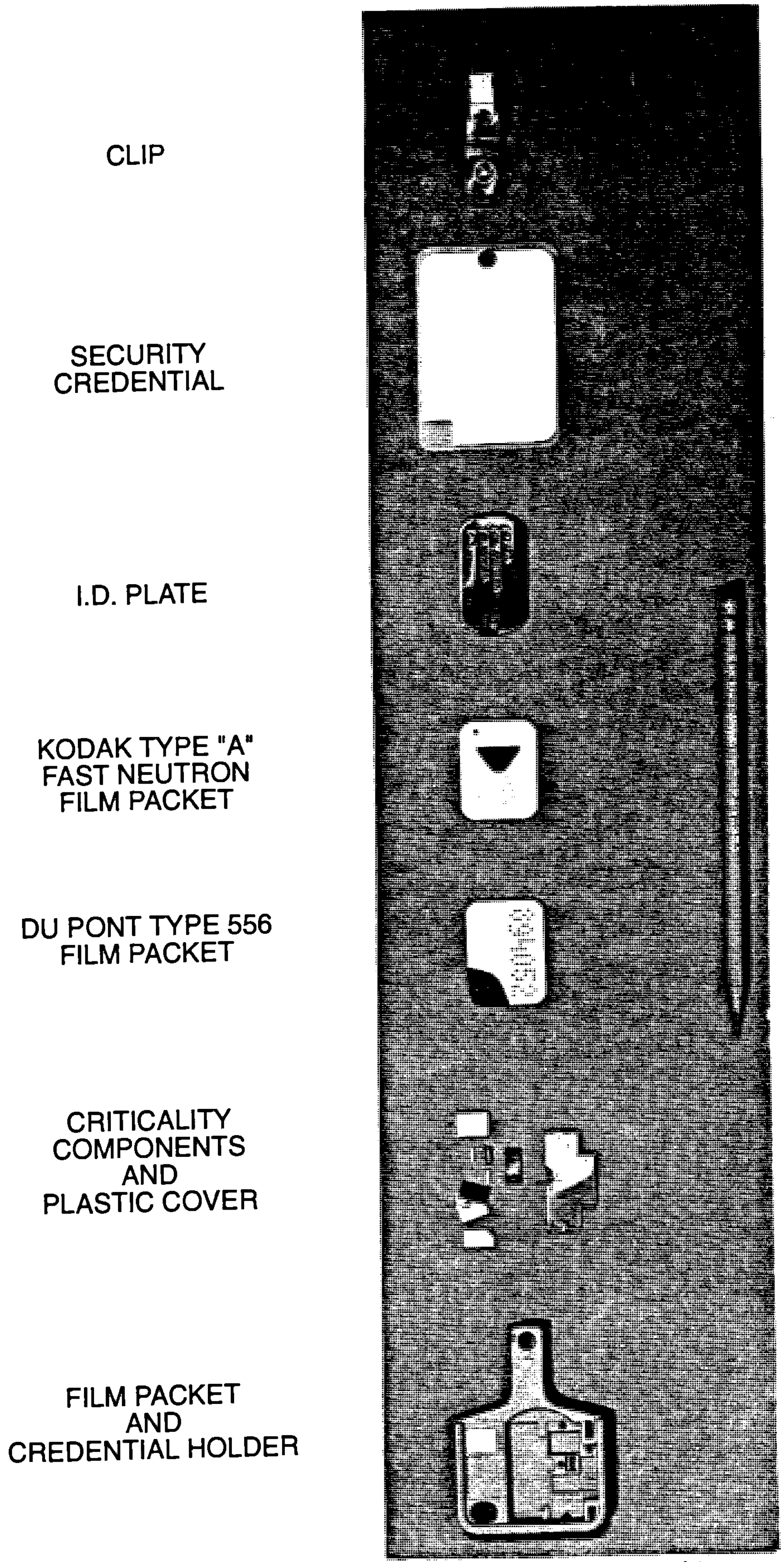


Figure 2-5. NTS combination personnel dosimeter and security credential holder (1966).

exposure ranges of the two components were 30 mR to 10 R and 10 R to 800 R, respectively. The other components of the film badge, with the exception of the elimination of the Kodak NTA film from the film packet, remained essentially the same.

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 the Area Access Register and added to the yearly and quarterly accumulated exposures. This daily NTS radiation exposure report was used until results of film packet processing were included in the dosimetry record. Pocket dosimeter readings were only used as estimates because such readings were less accurate than the doses of record determined by processing film packets.

This use of Area Access Registers helped to maintain personnel exposures below the whole body exposure guides listed in Chapter 0524, 3 rem per quarter and 5 rem per year. Personnel whose accumulated exposure was in excess of 2.5 rem per quarter or 4.5 rem per year (as recorded on the exposure report plus any pocket dosimeter reading since the report) were advised not to enter radex areas, and their supervisory personnel were also notified. DoD personnel involved in the events discussed by this report had accumulated doses substantially below these control guides.

2.7.4 Additional Methods Used to Control Radex Areas.

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

A. <u>Work accomplished</u> - Which people worked where 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 the reason for their visit were included where possible. The 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 type of entry were accidents, high-volume water seepage, or any other occurrence of an unusual nature.

D. Surveys and samples - Routine surveys and samples were recorded as routine. However, the requester's name was required for special surveys and samples.

E. Date and signature - The date and shift were entered at the beginning of the work period and the logbook 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 AEC NTSO SOP Chapter 0524, "Radiological Safety" (see Appendix D). 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 criteria for unconditional release on or off the NTS (less than 0.4 mrad/h fixed beta plus gamma at contact and/or 1,000 disintegrations per minute [dpm] per 100 cm^2 of nonremovable plutonium alpha; and less than 1,000 dpm/100 cm^2 of removable beta plus gamma and/or 100 dpm/100 cm^2 of swipeable plutonium alpha). Items exceeding these limits but below radex area levels could be conditionally released and moved onsite only.

2.8 TELEMETERED MEASUREMENTS OF RADIATION LEVELS.

Beginning in the early 1960s, 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 1 mR/h to 1,000 R/h and from 100 mR/h to 100,000 R/h continuously monitored locations of concern after being calibrated and emplaced prior to each event. Ion chamber detectors were hard-wire linked by telephone trunk lines to exposure rate meters at a central console in CP-2.

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

2.8.1 Telemetry System in Use.

During the time period covered by this report, several radiation telemetry systems were developed and used at NTS for specific applications depending upon distance, terrain, environment, and operational needs. All the detection units and components developed or in use during this period are listed below:

A. Remote Data Station (RDS).

The RDS unit, (in use 1962-1965) built by the National Bureau of Standards, used a Geiger-Müeller (GM) tube as the detecting element and transmitted signals by hard wire. The DC current from the GM tube was converted to frequency by running it through an oscillator circuit and was read as cycles per second which could be equated to roentgen rate readings. The unit was very efficient for transmitting signals over long distances, but had limited exposure-rate range, 10 mR/h to 10 R/h, and also lacked shock resistance capability. The RDS was modified for use at the NTS, but its use was later discontinued because of its inadequate exposure-rate range.

B. <u>Area Remote Monitoring Station (ARMS)</u>.

This unit (in use 1962-1967) consisted of a Tracerlab TA-6 (GM tube) gamma detector with a Model 261 direct readout meter, having a range of 0 to 10 R/h and 0 to 100 R/h. The hard-wire system had a 35-mile transmission range and limited shock resistance capability. Ground shock caused failure of the units, and their use was discontinued.

C. <u>Radector Monitoring Station (RMS)</u>.

This unit (in use 1962-1965) had Radector portable electronics including the Neher-White ionization chamber used for remote radiation detection. The RMS could transmit signals for 35 miles by hard wire, had direct readout, and had good shock-resistance capability. Descendants of the RMS were part of the Remote Area Monitoring System (RAMS) later used for DOE and DoD underground tests.

D. <u>Radio-Link Telemetry</u>.

This EG&G-developed system (in use 1962-1967) was a line-of-sight radio-linked system, transmitting information on VHF frequencies from a field unit to a main control console. The ionizing radiation-induced signal was read as cycles per second on a signal event-per-unit-time meter. Detectors provided information which automatically displayed on digital tape showing the time of measurements, locations, and radiation intensities. The system did not have the desired range or battery life for all applications, but was valuable in areas where no hard-wire transmission was available.

E. <u>Digital Data System</u>.

The Digital Data System (in use 1967-1972) was a multichannel, radio-linked, remote gamma radiation monitoring system. The detection unit and communications consisted of a RAMP-4 detection unit and probe hard-wire linked to a field trailer where signal data were digitized and transmitted via UHF to a trailer at the CP. The readout consisted of a typewriter, a punched tape, and a digital printer. All three operated simultaneously to provide current operational data, permanent records, and the capability for reproduction of data at any future time. This system was used primarily in remote areas where hard-wire communications did not exist. Communications between the field trailer and the CP were accomplished via radio net. The radio net was assigned prior to each event for use during installation, check-out, and during and after each event.

F. Well Logging Unit.

This unit was a Jordan ionization chamber gamma detector (in use 1967-1972) with a glass-head thermistor capable of obtaining gamma radiation or temperature measurements either separately or simultaneously. It was used at drill sites for postevent hole radiation and temperature measurements. Radiation detection ranges were 0.5 mR/h to 500 R/h, and temperature ranges were 0 to 350°F.

G. Remote Area Monitoring System (RAMS).

The principal piece of equipment used to form a RAMS was the RAMP-4. The RAMP-4 was a multichannel, hard-wire linked, remote area gamma radiation monitoring (telemetry) system (in use since 1966), designed and modified by Radsafe and produced by Victoreen Instrument Corporation. It consisted of a probe (Figure 2-6), which used a Neher-White radiation sensing element, hard-wire communication to the readout console (Figure 2-7) up to 35 miles away, and components of Victoreen Radector instruments with recorders for readout.

The readout covered six logarithmic decades (two three-decade scales) to provide a usual range of 1 mR/h to 1,000 R/h with a relative accuracy of ± 15 percent over the temperature range of -10 to 150°F. Extended range RAMS units provided a range from 100 mR/h to 100,000 R/h.

A permanent array of 20 to 35 telemetry stations throughout the NTS, as designated by DOE, was maintained and operated continuously. Temporary telemetry arrays for

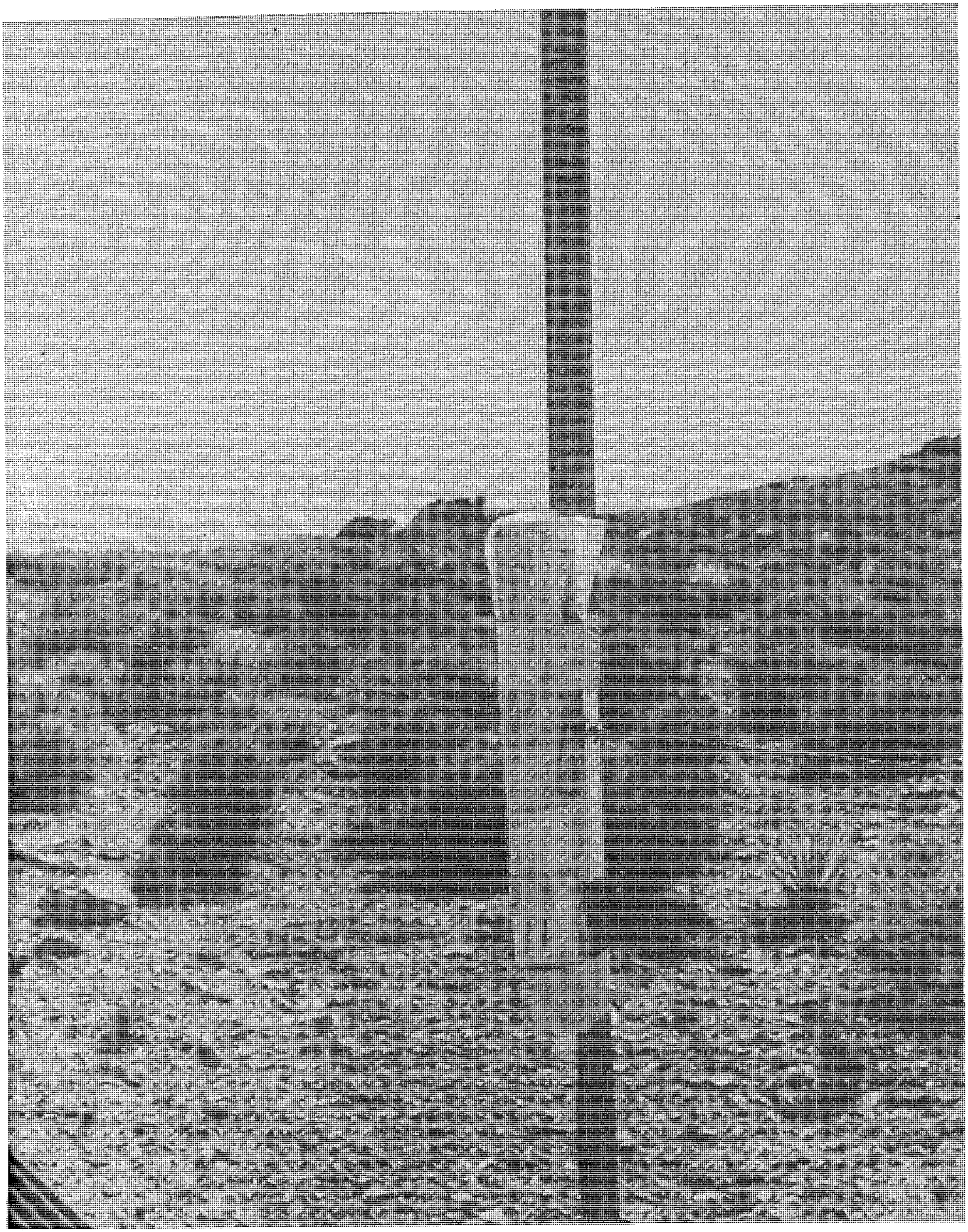


Figure 2-6. Neher-White RAMS probe.

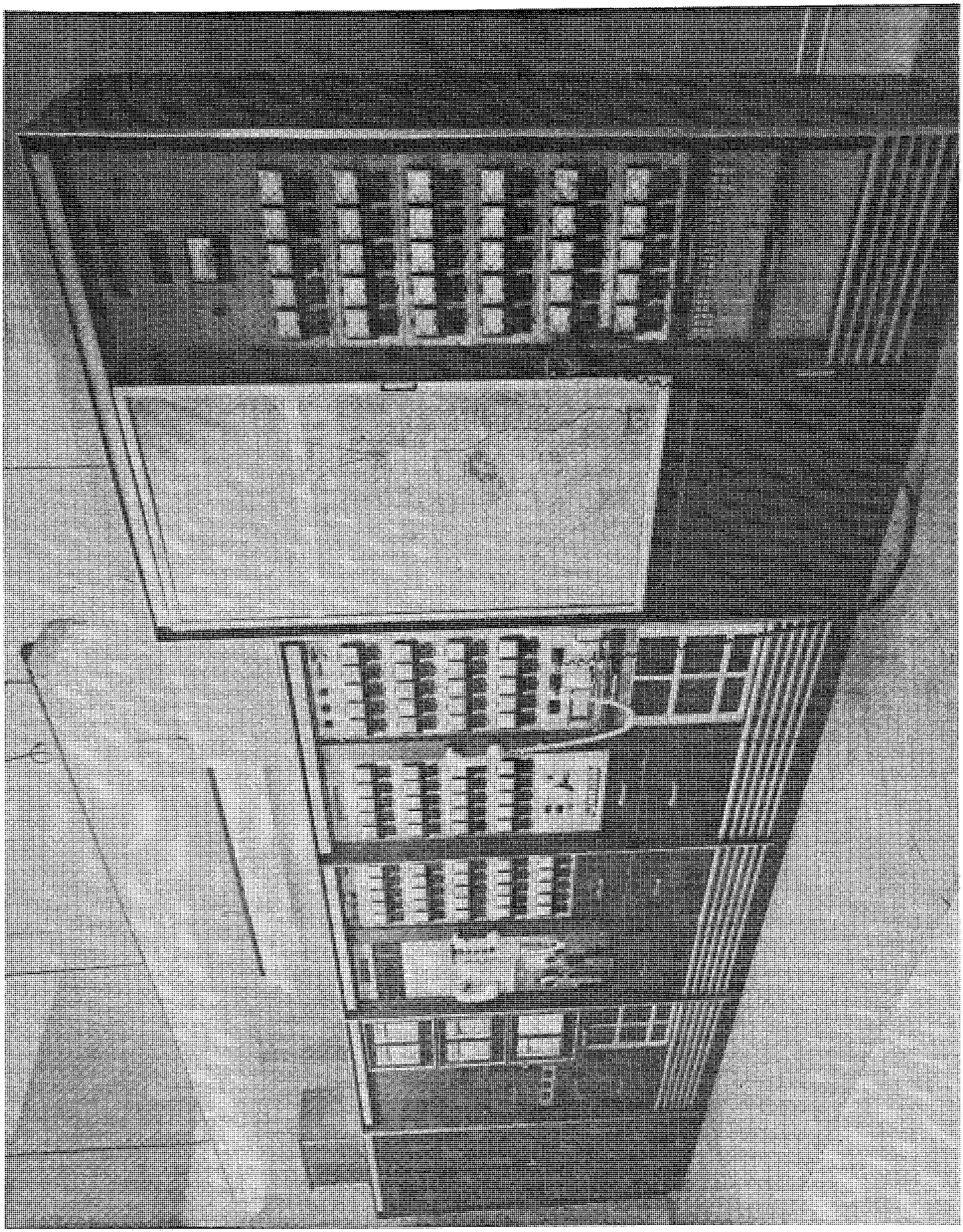


Figure 2-7. RAMS readout console.

DoD events varied between 15 and 50 stations depending upon the area or tunnel event location.

2.8.2 Remote Area Radiation Detection Monitoring Support.

Approximately 20 detector units were positioned in the test area before a shaft event to continuously monitor radiological conditions and assess exposure rates before the test area was entered after detonation. Detectors were placed in circular arrays at appropriate distances from surface ground zero (SGZ) which varied with device yield and predicted wind direction (See Figure 2-8). RAMS units for tunnel events were placed somewhat differently based on each tunnel layout. Variable numbers of detectors were used aboveground and underground during tunnel events and are discussed in each event section. The additional 20 to 35 permanently established remote radiation detector stations operated continuously at living areas, work areas, and other locations throughout NTS (Figure 2-9). Event-related temporary telemetry detectors operated from zero time until it was determined that release of radioactivity probably would not occur, or until any released radioactivity had decayed to near-background levels at the telemetry stations. For some of the earlier events, readout locations were positioned near the forward control point (FCP) or at locations where telephone lines were available, in addition to the readouts located at CP-2.

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

2.9 AIR SUPPORT REQUIREMENTS.

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

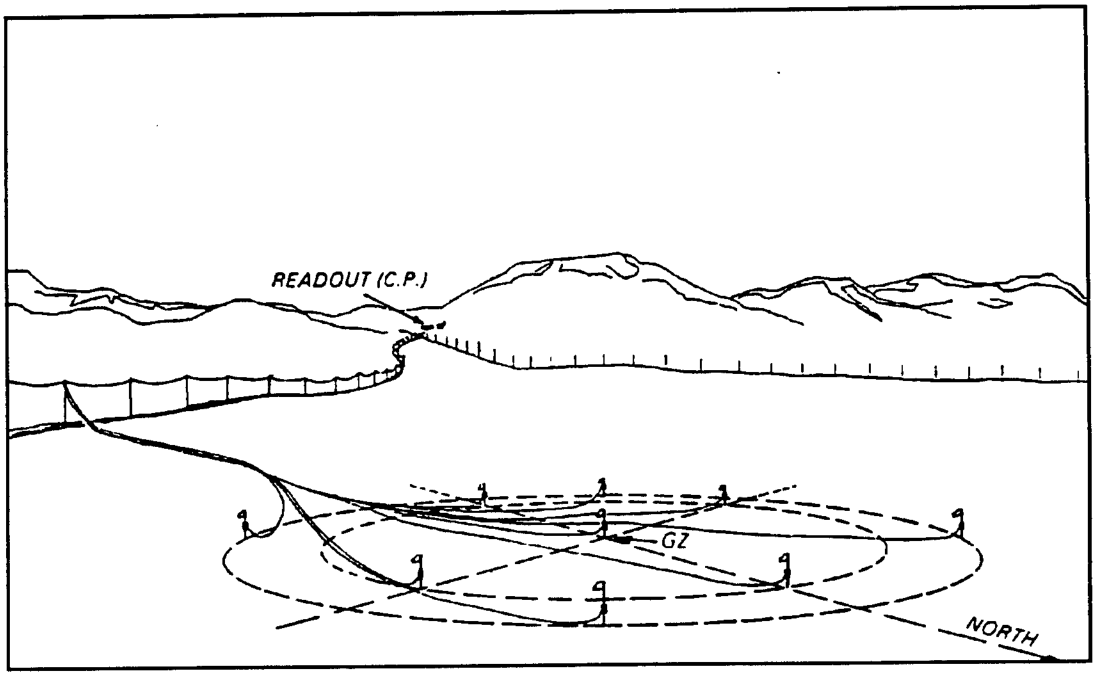


Figure 2-8. Typical remote radiation detection monitoring system for shaft emplacement site.

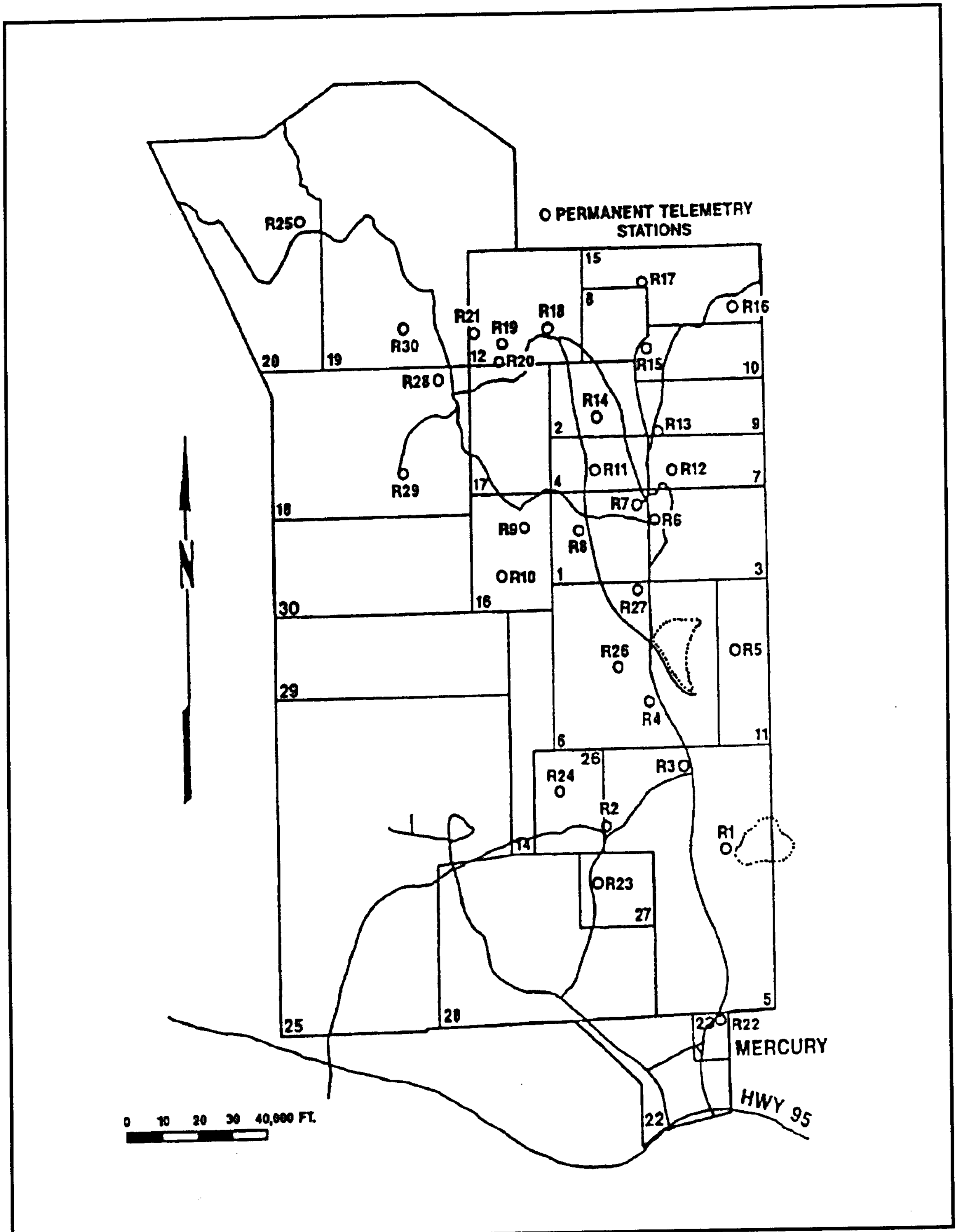


Figure 2-9. Typical permanently-established remote radiation detection station operated continuously throughout the NTS.

2.9.1 Changes in Air Support Requirements.

After 1962, Air Force cloud-sampling and cloud-tracking aircraft generally were not required except for cratering events conducted by the DOE 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 changes occurred in the fission product ratios previously used for analysis of atmospheric detonation cloud samples. The value of analyzing particulate and gaseous cloud samples to determine characteristics of a detonation decreased accordingly.

The first change in cloud sampling and tracking support was the use of a lighter Air Force aircraft, the U-3A, with an Air Force pilot and EPA monitor. The EPA monitor also performed aerial monitoring of selected locations near surface ground zero and along the path of any effluent cloud. This air support later was performed by EPA and contractor personnel in their own aircraft. Radioactive effluent was detected onsite for TAPESTRY, AJAX, AND CAMPHOR Events, and offsite for DES MOINES. No effluent was detected either onsite or offsite for CYPRESS event.

Perimeter sweeps continued to be conducted daily by Air Force and Security personnel during reasonable flying weather, to ensure that unauthorized vehicles were not entering the NTS over rough terrain or around security barricades on secondary roads. The L-20 aircraft, used prior to 1968, were replaced by helicopters and other aircraft. 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 ensure 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 con- tractor and military photographers and Radsafe monitors.

2.9.2 Radsafe Support for Indian Springs Air Force Auxiliary Field Personnel.

Radsafe support facilities had been established at Indian Springs Air Force Base (ISAFB) about 20 miles southeast of Mercury, during earlier atmospheric nuclear testing. During 1962 and subsequent DOE and DoD underground tests requiring support aircraft staged from ISAFB (which became Indian Springs Air Force Auxiliary Field, ISAFAF, in 1968), REECo provided all Radsafe support functions at the NTS. This included monitoring personnel stationed at the ISAFAF Radsafe Quonset facility and maintaining a complete stock of film dosimeters (badges), radiation detection instruments, and anticontamination clothing and equipment for use by air and ground crews.

Radsafe monitors issued and exchanged film dosimeters, 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.

2.9.3 Radsafe Support for Helicopters.

ISAFAF Radsafe support extended to all participating aircraft. However, special helicopter Radsafe procedures were implemented because these aircraft landed at NTS and staged from helicopter pads located east of Mercury Highway near the CP and FCP areas. Helicopter pilots usually landed at these locations and were briefed on their scheduled mission or other operational requirements.

If the mission involved possible contamination of the aircraft, Radsafe monitors lined the aircraft floor with plastic (or kraft paper) secured with masking tape to facilitate decontamination. Film badges and pocket dosimeters were issued to pilots and crew members, and anticontamination clothing was available if needed.

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

SECTION 3

DES MOINES EVENT

3.1 EVENT SUMMARY.

The DES MOINES event was a Lawrence Radiation Laboratory (LRL)-sponsored, weapons-related test conducted at 1400 hours PDT on 13 June 1962, with a yield of less than 20 kilotons. The device was detonated in the U12j.01 drift of J tunnel complex (Figure 3-1), emplaced 1,050 feet from the tunnel portal at a vertical depth of 650 feet. The purpose of the event was to test a nuclear device intended for a specific type of weapon system.

The five DoD-sponsored Vela Uniform experiments conducted during this event were designed to improve the capability of detection, identification, and location of underground nuclear explosions. Government agencies and DoD-contractor personnel participated in these projects.

Almost immediately after detonation venting of radioactive effluent occurred at surface ground zero (SGZ), then from the U12j.01 vent hole, and finally through the portal (Figure 3-2). Sustained gas flow started at H+170 milliseconds. By H+0.9 seconds, heavy dust scattering and rock avalanching had started over the mesa. By H+12 seconds, debris, sand, and gases were being exhausted from the tunnel portal at a velocity of approximately 65 miles per hour. The release lasted approximately five minutes. The cause of the release was attributed to stemming failure around the device. Tunnel stemming techniques were still in the developmental stages during these early tunnel events. Radioactive effluent from this test was detected both onsite and off the NTS and also on Nellis Air Force Range complex.

3.2 PREEVENT ACTIVITIES.

3.2.1 Responsibilities.

Safe conduct of all DES MOINES project activities in Area 12 was the responsibility of the LRL Test Group Director, subject to controls and procedures established by the AEC Test Manager.

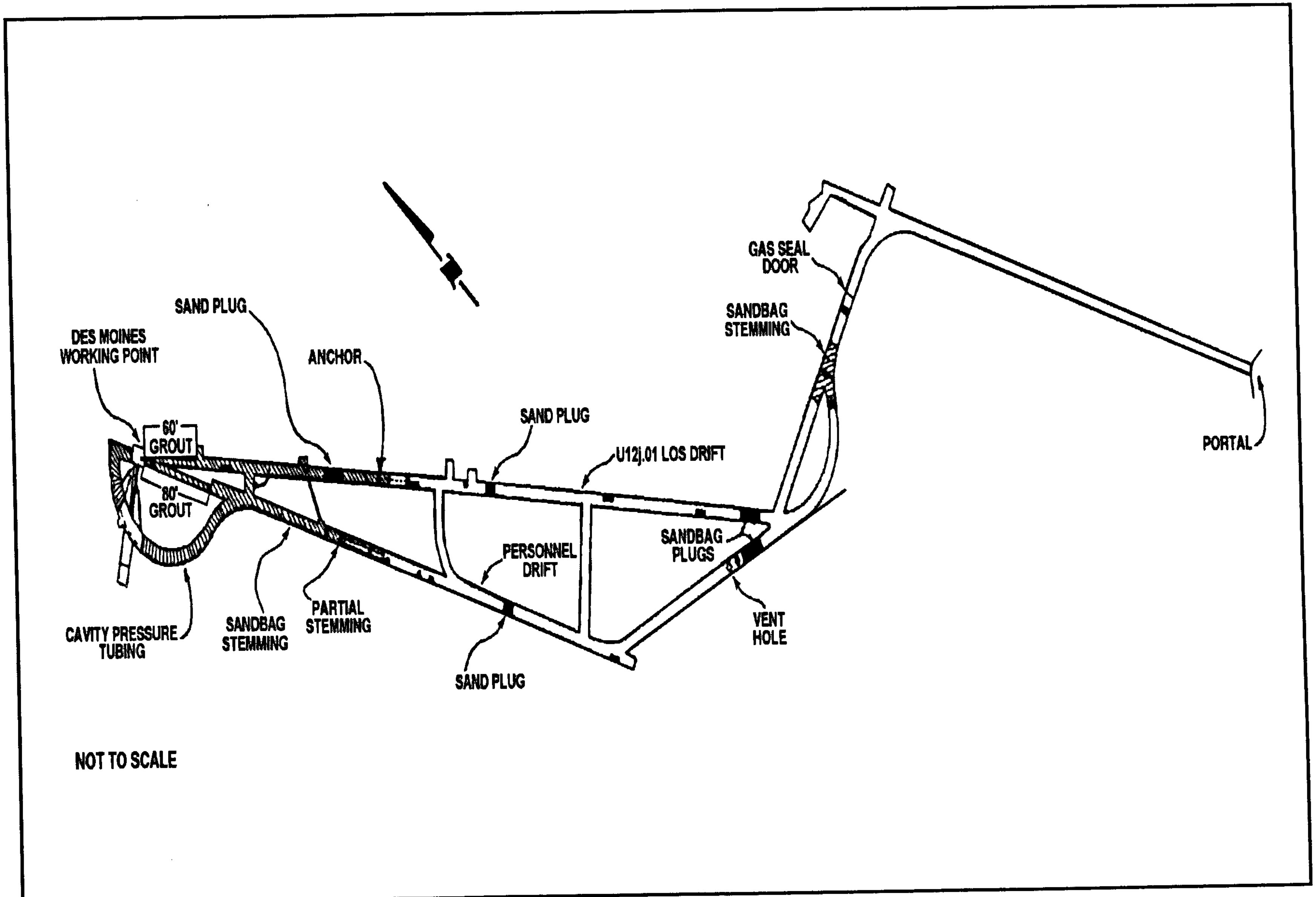
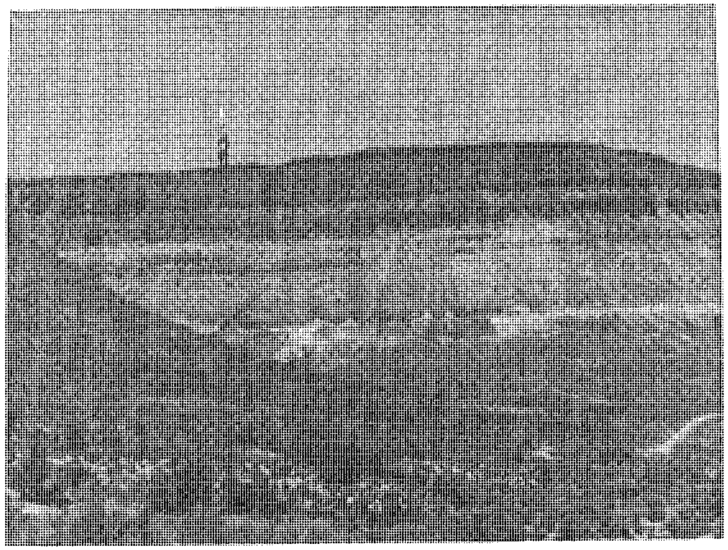
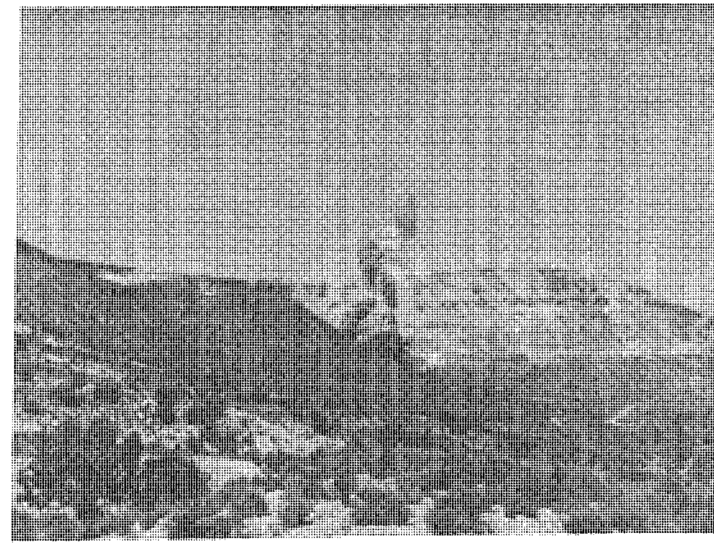


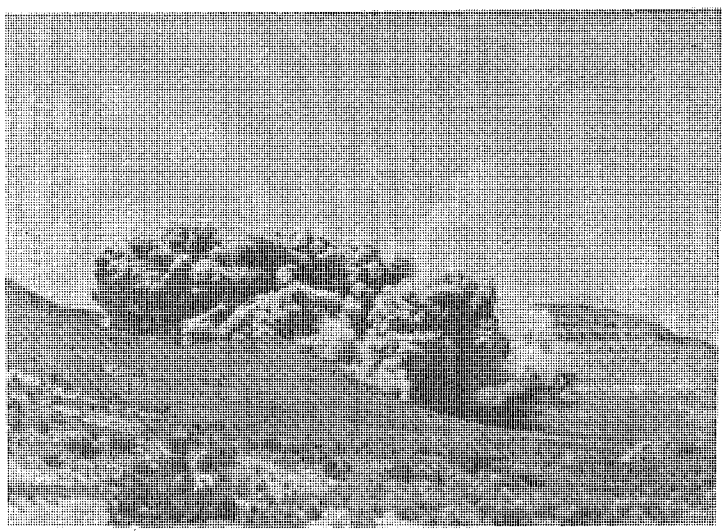
Figure 3-1. DES MOINES event - tunnel layout.



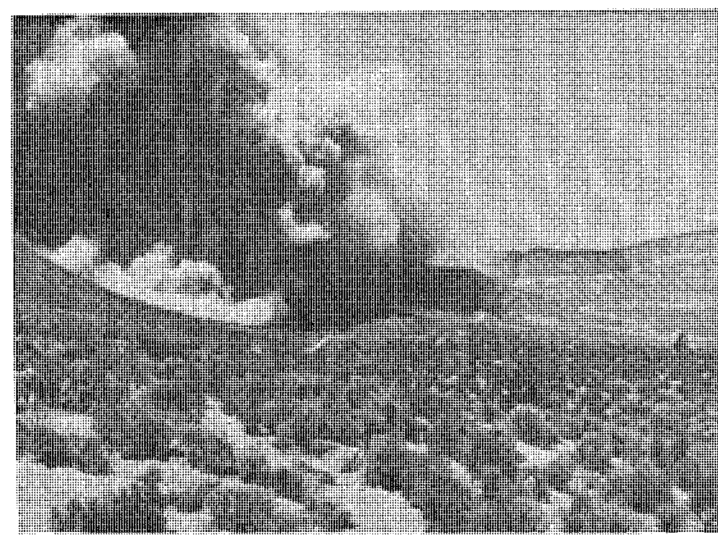
H+8 Seconds



H+15 Seconds



H+40 Seconds



H+2 Minutes

Figure 3-2. DES MOINES event - venting sequence.

The AEC Test Manager was responsible for safety of the public and onsite personnel during the test.

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

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

Firing circuits and timing signals were the responsibility of EG&G. Responsibility for stemming and arming the device was assigned to LRL, SLA, and EG&G.

3.2.2 Planning and Preparations.

A. Tunnel Facilities Construction.

Construction of the I, J, K tunnel complex began in October 1961, one month after the U.S. resumed testing (15 September 1961) and continued until after 30 June 1962. DES MOINES tunnel construction work was done on a "crash" basis.

The tunnel was driven into the mesa at an elevation which would provide the maximum overburden consistent with expected device yields (about 650 feet of overburden for this event). Concurrent with tunnel construction, diagnostic and vent holes were drilled from the surface of the mesa. The diagnostic bunker and trailer revetments (alcoves) were mined out of the side of the mountain adjacent to the tunnel portal.

While installing the line-of-sight (LOS) pipe, sand baffles and a 10- to 12-foot thick concrete blast collar fitted with a plug were also installed. After most of the tunnel construction was completed, detector pads were installed near the working point (WP) in the LOS drift. The LOS pipe was set on a stand and checked for alignment. Simultaneously with this work, Rad-Chem pipes (used for sampling nuclear debris that would be chemically analyzed to determine the yield) were installed. Figure 3-1 shows the LOS and personnel drifts were stemmed with a type of rock-matching grout to 60 and 80 feet, respectively, from the WP. Both drifts were then stemmed with sandbags to approximately 275 feet from the WP to protect experiments and other underground workings, located in tunnel alcoves, from blast effects and radiation exposure. Sandplugs at various points along the drifts and also behind the Gas Seal Door (GSD) were added for containment purposes.

Scientific cabling was run in from the portal, and dry runs were made concurrently with the installation of the cable. The signal systems and Area Remote Monitoring Stations (a telemetry system used before the present-day Remote Area Monitoring System [RAMS] was developed) were installed and tested at the same time. Scientific cabling to the bunkers and to the diagnostic trailers to support contractor experiments were connected and tested. This included installation of photographic, seismic, and geophone stations.

Scientific program studies included the five DoD-sponsored Vela Uniform projects that involved seismic effects studies and still and motion picture photography. The experimenter organizations included: the U.S. Coast & Geodetic Survey (USC&GS), conducted strong motion and intermediate range seismic measurement studies both onsite and off the NTS (Projects 1.4 and 8.1); Geotechnical Corporation (GEOTECH), conducted long-range seismic measurements using 40 transportable seismic stations within the 48 contiguous states at varying distances from the NTS up to 2,500 miles (Project 8.4); the U.S. Army Pictorial Center (USAPC), provided documentary still and motion picture photography coverage (Project 9.2.); and Lookout Mountain Air Force Station (LMAFS), provided photographic coverage for public information purposes, including television and newsreel pictures (Project 9.3.).

The AEC-sponsored SRI Projects 29.1 and 29.4, studied air pressure and earth motion in tunnel systems. The DES MOINES air pressure records showed the time at which radioactive gases broke through the stemming, then through successive sandplugs, and finally through the blast door. Figure 3-3 shows an SRI experiment setup.

After checking the diagnostic systems, installation of sandbag stemming began. The device was brought in at D-4 days while dry runs continued. Installation of additional equipment, both in the experimenter alcoves and the trailer park continued as dry runs were conducted. The final dry run was completed on 12 June after which final stemming and button-up operations began.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were conducted in accordance with AEC Manual Chapter 0524 and the requirements of responsible LRL representatives. Radsafe (REECo) provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimetry packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during dry runs. Radsafe monitors were briefed regarding reentry, sample recovery, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in tunnel reentry parties as needed. Radsafe personnel were also standing by at the Test Director's Barricade prior to detonation to perform surveys and provide emergency support as directed. Routine support included issuing anticontamination equipment and material, portable instruments, and dosimeters; operating area control check sta-

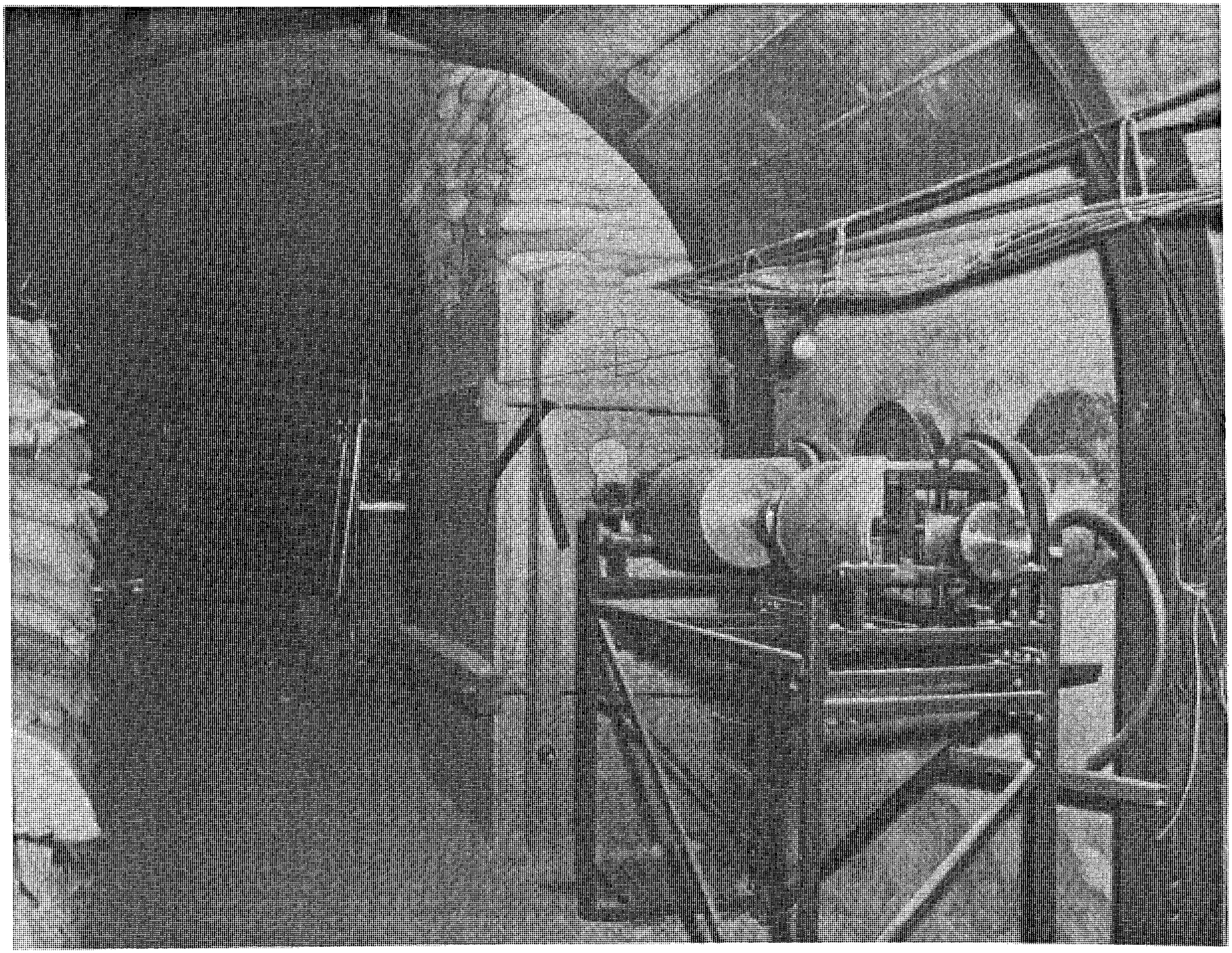


Figure 3-3. DES MOINES event - an SRI experiment.

tions; and performing 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.

Decontamination units were positioned at entrances to contaminated areas. Personnel and equipment, including drill rigs and other equipment used in postevent activities also were monitored and decontaminated, as necessary.

C. Telemetry and Air Sampling Support.

In addition to the 40 telemetry stations throughout the NTS that operated continuously during the test period, 14 surface radiation monitoring stations were installed and calibrated by REECo Radsafe. Ten additional radiation monitoring stations operated by the user laboratory (LRL) were located in J tunnel and in the diagnostic bunkers. Table 3-1 lists telemetry unit locations operated by Radsafe and Figure 3-4 shows these locations. All readings were reported via radio net to the readout station at the Test Director's Barricade.

High-volume Staplex air samplers, equipped with MSA organic filter cartridges and 8-inch by 10-inch glass fiber prefilters, were positioned at the following locations: E tunnel portal, Area 12 Camp, the Test Director's Barricade, Area 15, Security gate 700, and Area 9.

The United States Public Health Service (USPHS) operated 32 air sampling stations and 7 recording radiation monitors in the offsite area. Twelve mobile monitoring teams were fielded for offsite surveillance activities.

Table 3-1. DES MOINES event telemetry unit locations 13 June 1962.

SURFACE

Station	Location	Telemetry Used
1	U12j portal	RMS[8]
2	U12j.01 vent	RMS[8]
3	U12i.01 vent	RDS[8]
4	1,000 feet east of Stake A-5	RDS
5	Stake A-8	RDS
6	Stake A-11 near SRI trailer	RDS[8]
7	Stake A-1	RDS[8]
8	Stake A-15	RDS[8]
9	U12p at Stake A-6	RDS
10	U12k.01 vent	RDS
11	Stake A-17	RL
12	Stake A-14	RDS
13	Stake B-6	RL
14	Area 12 Trailer Park	RL

RMS - Radector Monitoring Station

RDS - Remote Data Station

RL - Radio Link

[8] Stations rendered inoperative by detonation.

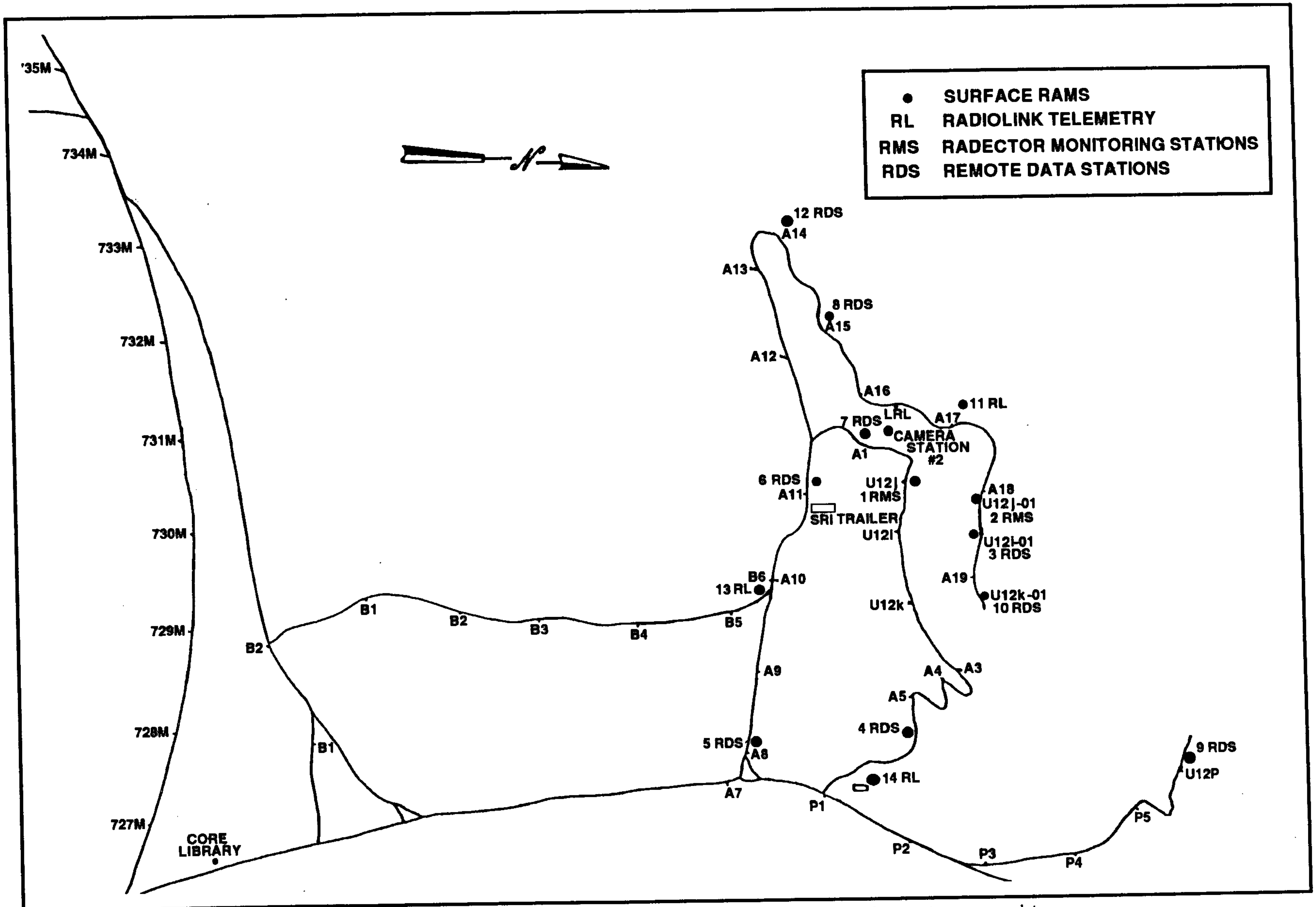


Figure 3-4. DES MOINES event - surface telemetry units.

D. Security Coverage.

Beginning at 1800 hours on 12 June 1962, muster and control stations for the I, J, K tunnel area were established. 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 the use of roadblocks, access authorizations, and a Schedule of Events. Parties could enter the area only with the permission of the Test Group Director or Test Manager.

Final sweep and clearance of the area began at H-6 hours to ensure that contractor and agency personnel not associated with this event were out of the closed area. By H-2 hours, all personnel except arming and firing party members were clear of the closed area.

E. Air Support.

The USAF provided a U-3A aircraft, manned by an Air Force crew, for cloud tracking missions. Aerial survey measurements were conducted by a USPHS monitor using these radiation measuring instruments: a Precision Model III scintillator with an added transistorized amplifier feeding an Esterline-Angus strip chart recorder, an EG&G aerial monitor, and an AN/PDR-39 survey instrument.

3.3 EVENT-DAY ACTIVITIES.

3.3.1 Preshot Activities.

On 12 June 1962 at 1800 hours all persons except the arming party, the tunnel button-up party, and the security guards were out of the tunnel and clear of the muster area. Permission was granted to arm the device while final sandbagging, stemming, and button-up activities continued. By 1100 hours on 13 June button-up was completed. All unnecessary buildings, diagnostic trailers and maintenance shacks were removed from the portal area and the immediate vicinity. All line power to the area was switched off and only instrument power remained during firing.

A weather briefing for the Test Manager, Advisory Panel and others was conducted in the CP-1 Conference Room at 1200 hours. Conditions for the test were favorable and the countdown began at 1330 hours.

The DES MOINES device was detonated at 1400 hours PDT on 13 June 1962.

3.3.2 Test Area Monitoring.

Within milliseconds after the detonation, a fire ball was seen coming from the top of the mesa (SGZ), and seconds later venting occurred from the U12j.01 vent hole. By H+12 seconds debris, sand, and gases were spewing from the tunnel portal.

Telemetry measurements began at 1400 hours on 13 June 1962. Of the 14 above ground radiation monitoring stations, six were rendered inoperative almost immediately when the detonation shock wave disabled an electrical junction box near the tunnel portal. The eight other stations continued to function normally. The initial reading at the J tunnel portal was greater than 10,000 R/h, after which that station malfunctioned. Telemetry units at the U12k.01 bunker and stakes A-17, A-14, and B-6 locations were all reading greater than 10 R/h by 1412 hours (Figure 3-4). By 1640 hours the maximum reading was 4.5 R/h at the U12k.01 bunker. Radiation monitoring stations were left operating for seven days allowing decay rate data to be obtained.

The eight user-placed monitoring stations located in J tunnel between the personnel-LOS drift junction to the portal were also rendered inoperative milliseconds after detonation. However, stations in the diagnostic bunkers survived.

As part of the effluent cloud initially moved south from the force of venting out of the portal and vent hole, radiation intensities increased at the Test Director's Barricade which was located approximately 9,000 feet south of the tunnel portal. As a precaution, personnel were evacuated for a short period of time. As the cloud approached the Test Director's Barricade, where the maximum reading was 250 mR/h, 20 to 30 miles per hour(mph) winds moved the cloud in a northeasterly direction away from the barricade.

Aerial monitoring began almost immediately after detonation. The first pass over the cloud by Air Force and USPHS monitor personnel, in a U-3A aircraft, began at 1402 hours at an elevation of 8,500 feet Mean Sea Level (MSL). The J tunnel elevation at the portal is 5,635 feet MSL. The cloud direction was five degrees east of north, and monitoring instruments recorded an exposure rate in excess of 50 R/h inside the aircraft. After the pass, the reading inside the aircraft was 20 mR/h, and by 1412 hours the reading had dropped to 15 mR/h. The trailing edge of the cloud was 1.5 miles from ground zero (GZ) by this time. During a pass at five miles north of SGZ and 14,750 feet MSL at 1415 hours, instrumentation inside the aircraft recorded 13 R/h. By 1425 hours, when the cloud was seven miles from SGZ, the reading was 100-200 mR/h at 15,500 feet MSL.

Cloud tracking continued to the north between Current and Duckwater, NV (over 100 miles from the tunnel portal) where the mission was finally terminated at 1730 hours because the aircraft fuel supply was low. The aircraft returned to Indian Springs Air Force Base (ISAFB) at 1840 hours.

3.3.3 Initial Surface Radiation Surveys and Recovery Activities.

Initial survey teams conducted surface monitoring beginning at 1510 hours on the day of the detonation. The maximum reading recorded at the U12k.01 portal was 5 R/h at 1548 hours and at Stake A-10 the reading was 5 R/h at 1604 hours. However, a DoD survey monitor, stationed at 0.5 miles south of Stake A-11, recorded 20 R/h (probably due to expulsion of debris from the tunnel) at 1401 hours. This reading decreased rapidly to 500 mR/h by 1405 hours. A survey on Pahute Mesa from 1500 through 1545 hours at approximately 4.0 miles west of the west edge of Oak Springs Butte gave a maximum reading of 65 mR/h. By the next day, 14 June 1962, the SRI trailer area was still reading 10 R/h at 1446 hours while a reading at 200 feet from the U12j portal area was greater than 10 R/h at 1450 hours. By 17 June 1962, the SRI trailer area reading had decreased to 3.9 R/h.

Results of an initial monitoring survey (Figure 3-5) showed isodose curves for 13 June at midtime (i.e., data collected at equal time intervals before and after the stated time) 1530 hours. The 5 R/h line encompassed the canyon and mesa areas and extended east beyond the K tunnel portal. Exposure rates were extrapolated (i.e., dotted lines) because readings were only taken along the access roads. Isodose curves were not drawn to the north and west because there was no vehicle access to those areas. By 15 June at 0600 hours midtime radiation lev-

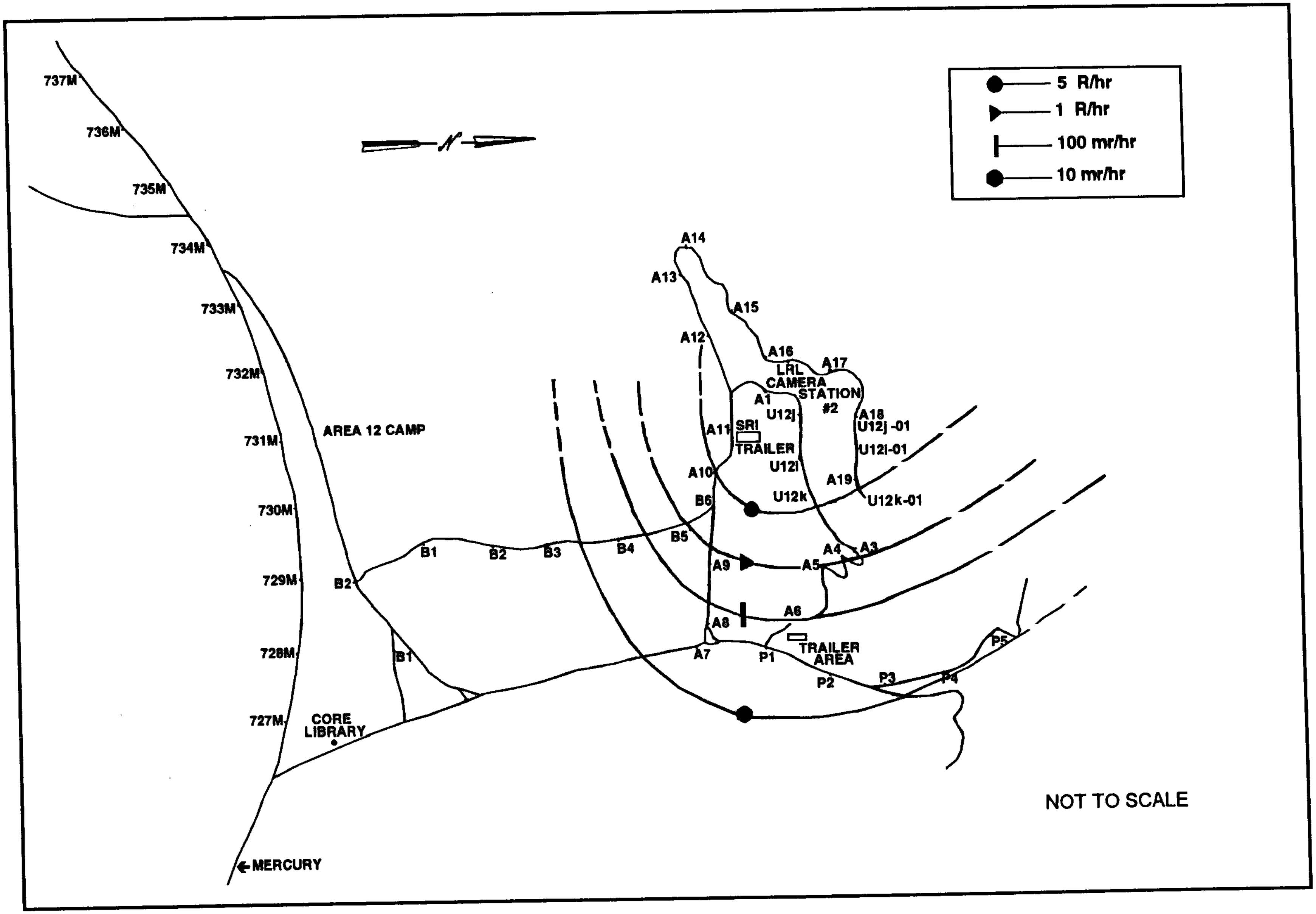


Figure 3-5. DES MOINES event - initial survey 13 June 1962 midtime.

els had decreased greatly to where the 1 R/h isodose curve was concentrated in the portal area, southward where debris was accumulated, and at the vent hole on top of the mesa (Figure 3-6).

Despite high radiation levels, and gusting and changing wind directions, recovery of data for Air Force Special Weapons Center (AFSWC) Projects 832.1, 836, and 835.2 had been made by 2000 hours on 13 June 1962. However, recovery of data for SRI Projects 816 and 818 at the SRI trailer park were delayed due to high radiation intensity levels. On 14 June at 1100 hours, a recovery party went to the SRI trailer area and brought one trailer and some equipment to the decontamination pad for field decontamination before sending it to the CP-6 decontamination facility, and on 15 June at 1000 hours, a second SRI trailer was brought to the decontamination pad. As soon as possible after firing (approximately D+4 hours), reentry crews removed film and other diagnostic data from trailers in the bunkers. However, continued venting prevented sample and other data recovery that day. Fallout trays, film badges, samples, and additional film recoveries were made by LRL and REECo Radsafe beginning on 14 June. On 15 June, LRL personnel went to the portal area to attempt to remove debris and make preparations for experiment recovery, however, because exposure rates were high, 650 mR/h, survey team members left the area in about two hours. On that same day, LRL personnel using a helicopter for access recovered samples from the mesa.

3.4 POSTEVENT ACTIVITIES.

Radiation surveys of the vent hole, tunnel, reentry tunnel portal areas and postshot drill hole areas continued. Radex area access requirements were maintained from D-1 until 4 July 1962.

3.4.1 Tunnel Reentry Activities.

Because radiation intensity levels were extremely high at the U12j portal area, barricades were placed on access roads after initial sample and equipment recoveries were made. Radiation surveys were made on each shift, and radex areas were established and updated accordingly. Sandbagging of the J tunnel portal area was done to reduce radiation exposures to personnel working at the J reentry tunnel portal area. Tunnel reentry to recover experiments from the instrument alcoves on 22 June was accomplished as the result of mining activities discussed below.

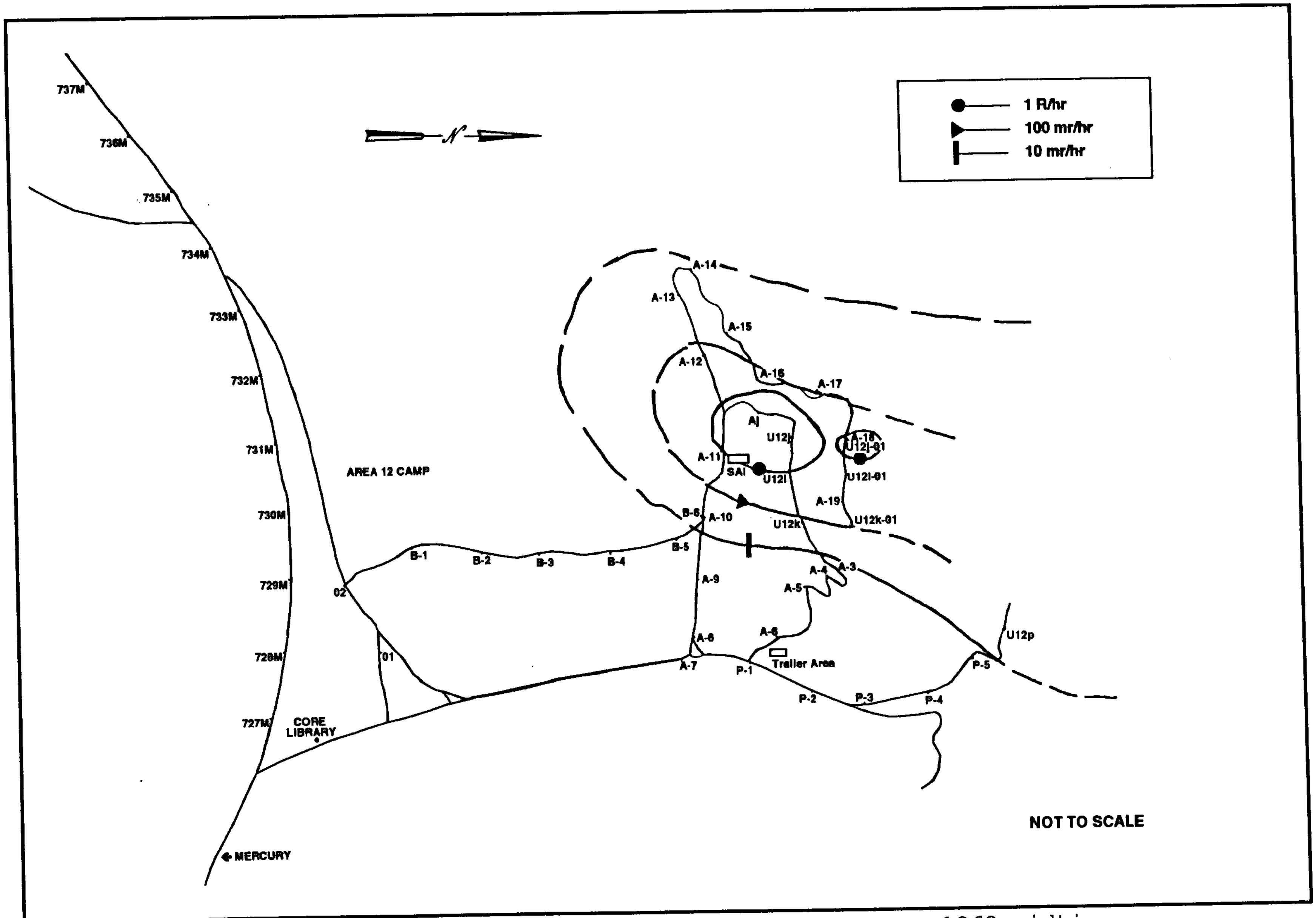


Figure 3-6. DES MOINES event - D+2 survey 15 June 1962 midtime.

3.4.2 Postevent Mining.

As indicated by the U12j.01A Reentry Plan, a reentry tunnel was partially mined before the DES MOINES event was detonated. This tunnel, approximately 140 feet west of the original tunnel, was initially driven 229 feet. As recorded in the Field Operations Tunnel Logbook, mining resumed in the J reentry tunnel on swing shift 18 June 1962. Miners, wearing respirators, continued mucking operations and blasting in the J reentry tunnel. The work area at the end of the reentry tunnel was reading 1 mR/h with no positive LEL detected. By 21 June, at 0730 hours, the tunnel was mined to 360 feet, the exposure rate was less than 1 mR/h, and no positive LEL was indicated. Readings of 200 ppm carbon monoxide and 20 ppm nitric oxide/nitrogen dioxide were observed. By 1930 hours on that same day, a hole had been drilled into U12j tunnel from the U12j reentry tunnel. A pipe was inserted into the drill hole and a sample of air was taken from U12j tunnel. The following readings were observed:

LEL - 100%
carbon monoxide - approximately 7000 ppm
nitric oxide/nitrogen dioxide - 1 ppm
exposure rate at face of U12j reentry tunnel - 2 mR/h
contact on return mud - 50 mR/h

An air sample was taken from the pipe inserted into the U12j tunnel for tritiated water analysis. The sample was collected between 1959 and 2024 hours. The sampling bottle was reading 3.5 mR/h and was sent to the lab for analysis. On 22 June, miners in full-face masks hammered into the sampling hole. The reading one foot inside the hole was 2.5 R/h. Miners broke through into the reentry drift of the U12j tunnel. After samples were taken and recoveries made, miners removed equipment and the U12j reentry tunnel was secured.

3.4.3 Postevent Drilling.

Drilling of postshot (PS) hole No. 1, located 75 feet west of SGZ, began on Pahute Mesa at 1700 hours on 20 June and continued until 29 June. The hole was predrilled to 400 feet and was extended to a depth of 800 feet. When the drill bit was pulled from the hole, the radiation level on the drilling platform was 3.5 mR/h and on the ground surrounding the drill rig the reading was 8-15 mR/h. Several core samples were taken at various depths (beginning at 720 feet) with a maximum core sample reading of 5 R/h. The core sampling operation for PS hole No. 1 was completed at 0030 hours on 1 July. A second postshot hole, located approximately 10 feet east of SGZ and predrilled to 600 feet, was drilled to a final depth of 775 feet. Work began on 27 June at 0230 hours and was completed by 2200 hours on 1 July. Several core samples were taken. All drilling and sampling equipment was decontaminated prior to final button-up of the area at 0900 hours on 3 July 1962.

3.4.4 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation levels were made on each shift. Results were recorded in the monitors' logbook.

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. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive material, or any other operation with a potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

The portal construction areas and the tunnel were mandatory hard hat and foot protection areas (safety shoes, safety boots, AEC-issued miner's boots, or toe guards). All personnel on the initial tunnel reentry teams had received training and used both the self-contained and McCaa two-hour breathing apparatus. Standard safety rules and regulations, as stated in the "U.S. Bureau of Mines Manual," were observed.

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

1. Army Materiel Command Regulations (AMER 385-224).

2. AEC Manual 0500 Series for the Nevada Test Site.[9]

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[9] Applicable parts of the AEC NTSO SOP 0550 series were not superseded until 1968.

3. Individual Safe Operating Procedures (by experimenter organization).

4. DES MOINES 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 that had been approved by the LRL Safety Coordinator.

3.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 1400 hours on 13 June 1962. While six stations were rendered inoperative by the blast, the other eight continued to provide readings until shut down at 1840 hours on 13 June. All underground monitoring stations were also destroyed.

Initial radiation surveys began at 1510 hours on 13 June and resurveys were conducted on a regular basis until the end of June. The maximum reading recorded by survey teams was 5 R/h at the U12k.01 portal at 1548 hours. However, a DoD survey monitor, who was located 0.5 miles south of Stake A-11, recorded 20 R/h at 1401 hours on 13 June.

Extremely high radiation levels at the U12j.01 portal prevented reentry through the tunnel portal. A reentry tunnel, U12j.01A, located approximately 140 feet west of the original portal that was partially mined before the event, was completed to meet the original U12j reentry drift. This resumption of reentry tunnel mining began on 18 June and breakthrough to the original tunnel was made on 22 June. Some experiments were recovered from the instrument alcove.

Two postshot holes were drilled to maximum depths of 800 and 775 feet, respectively. Several core samples were taken with a maximum core sample reading of 5 R/h. Coring was completed on 1 July, with final button-up of the area occurring on 3 July.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to DES MOINES radex areas from 13 June to 30 June 1962. These totals are shown below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	1,770	1,000	86
DoD Participants	23	1,000	280

The minimum detectable gamma exposure with the NTS film badge dosimeter was 30 mR. Weekly film dosimeter exposure records from 8 June through 30 June 1962 show that, in addition to the entries recorded on the Area Access Registers, ten additional DoD and DoD-contractor personnel received exposures that probably were the result of the DES MOINES event. For these ten individuals, the maximum exposure was 1,135 mR, and the average was 287 mR.

SECTION 4

TAPESTRY EVENT

4.1 EVENT SUMMARY.

The TAPESTRY event was a Lawrence Radiation Laboratory (LRL)-sponsored weapons-related test conducted at 1237 hours PDT on 12 May 1966, with a yield of less than 20 kilotons. The device was detonated in Area 2 (U2an) emplaced in a 48-inch diameter shaft at a depth of 810 feet. The purpose of the TAPESTRY event was to test a nuclear device intended for a specific type of weapon system. The DoD-sponsored add-on experiment program, NATIVE MIST, was conducted on a non-interference basis. Fifteen DoD contractors conducted over 20 projects as part of the NATIVE MIST program.

Ground shock from the detonation moved the vertical LOS pipe upward temporarily preventing the movement of the Exposure Building (also referred to as the Effects Room or Test Chamber) from surface ground zero (SGZ). Surface collapse occurred at approximately H+5 minutes, producing a subsidence crater about 300 feet in diameter and 24 feet deep. As shown in Figure 4-1, the Effects Room was not completely removed beyond the crater radius when subsidence occurred. However, there was no serious damage to experiments, and the majority of exposed materials were successfully recovered. Beginning at H+1.13 hours, a release of radioactive effluent occurred from the SGZ area. This minor seepage lasted for approximately 57 hours, but no radiation above background levels was detected by remote area monitoring beyond the 500-foot arc. One postshot release of radioactive effluent was detected from the ventline during drillback operations on 13 May 1966 beginning at 1600 hours and lasting for approximately 49 days. No radioactive effluent was detected offsite from any of these releases.

4.2 PREEVENT ACTIVITIES.

4.2.1 Responsibilities.

Safe conduct of all TAPESTRY project activities in Area 2 was the responsibility of the LRL Test Group Director, subject to the controls and procedures established by the AEC Test Manager.

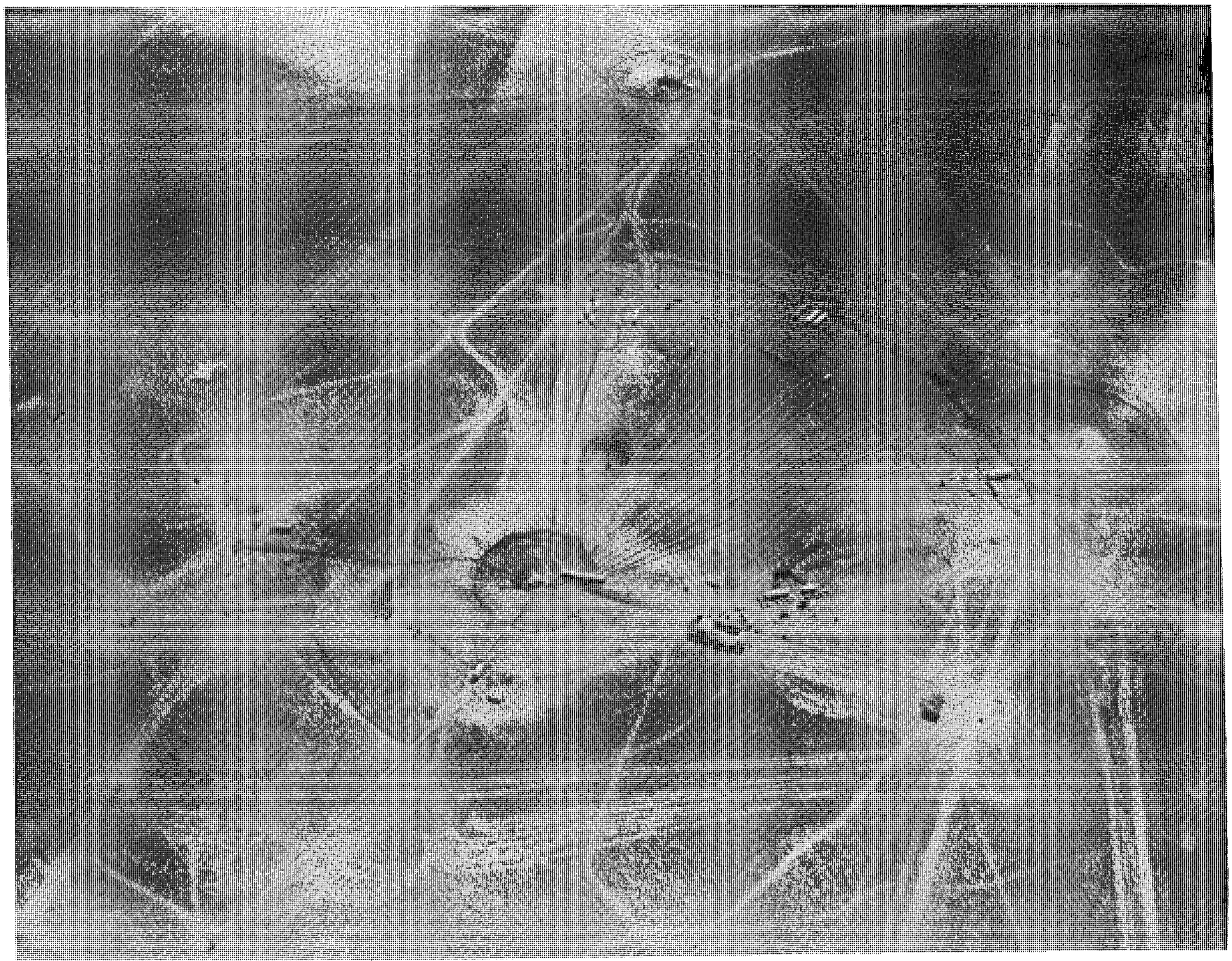

Figure 4-1. TAPESTRY event - aerial view of surface ground zero area showing the Effects Room being pulled away.

The AEC Test Manager was responsible for safety of the public and onsite personnel during the test.

Project agencies were responsible for designing, preparing, and installing 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 LRL fielded the device, the LRL Test Group Director was responsible to the AEC Test Manager for radiological safety within a 4,000-foot radius of SGZ. This responsibility was in effect from the time the device was moved to the zero site until device detonation. After device detonation, the AEC Test Manager relieved the LRL Test Group Director of this responsibility. REECo Radiological Safety Department (Radsafe) provided onsite radiological safety support services and was responsible to the LRL Test Group Director while the testing area was under his control. When the testing area was under the control of the AEC Test Manager, REECo Radsafe provided monitoring support, area control, and surveillance.

Firing circuits and timing signals were provided by EG&G. Responsibility for stemming and arming the device was assigned to LRL, EG&G, and Sandia.

4.2.2 Planning and Preparations.

A. Area Facilities Construction.

When constructing the TAPESTRY emplacement site, the TAPESTRY device depth of burial was reduced from 850 to 810 feet because the designed maximum expected yield decreased. This 40-foot reduction in the depth of burial was achieved by removing a portion of the LOS pipe between the high-explosive flap closures and the ball valves. In addition, two other design changes were made in the LOS pipe. The high explosive flap closures were relocated 40 feet further from the device in order to allow more time for the flaps to close before debris arrived, and five feet were added below the ball valves. The Test Ban Evaluation panel along with LRL and other authoritative NTS personnel determined that these modifications would meet all requirements imposed by the Limited Test Ban Treaty.

The test configuration and stemming plan (Figure 4-2) shows the device was emplaced in a 48-inch diameter, 831-foot shaft at a depth of 810 feet. The device was stemmed to approximately 380 feet with Overton sand. A forty-foot polymer plug covered the sand stemming. Above the plug was another 310 feet of Overton sand and a 20-foot polymer plug. A 10-foot thick concrete slab covered the plug. Locations of the closure valves and ball valves are indicated.

The Effects Room, containing DoD- and AEC-sponsored experiments, was positioned above ground zero (GZ). Figure 4-3 shows the A-Frame support being put in place over the Effects Room. Approximately 50 percent of the experiment area was allocated for LRL experiments, while SL and DASA each had 25 percent of the area. Extensive cables carried the data from experiments (Figure 4-4) to the recording stations in nearby trailers.

The major objectives of the DoD-sponsored experiments conducted under the NATIVE MIST program were to: (1) investigate the vulnerability of DoD warhead components; (2) determine detrimental effects on various missile components; and (3) study the effects of a radiation environment on reentry hardware.

The following is a partial list of contractor-agency experimenters: General Atomic Corporation (GA), electronics vulnerability studies; AVCO Corporation (AVCO), electronic components and Air Force systems studies; Army Missile Command (AMICOM), Army electronics and pyrotechnics studies; Lockheed Missile & Space Company (LMSC), Navy electronics, materials response, pyrotechnics experiments, and engineering and other support services; Aeronutronics, Division of Philco-Ford Corporation (AFC), materials response studies; Kaman Nuclear (KN), materials response and test instrumentation development studies; General Electric Company, Reentry Systems Department (GE), materials response and other studies; Applied Physics

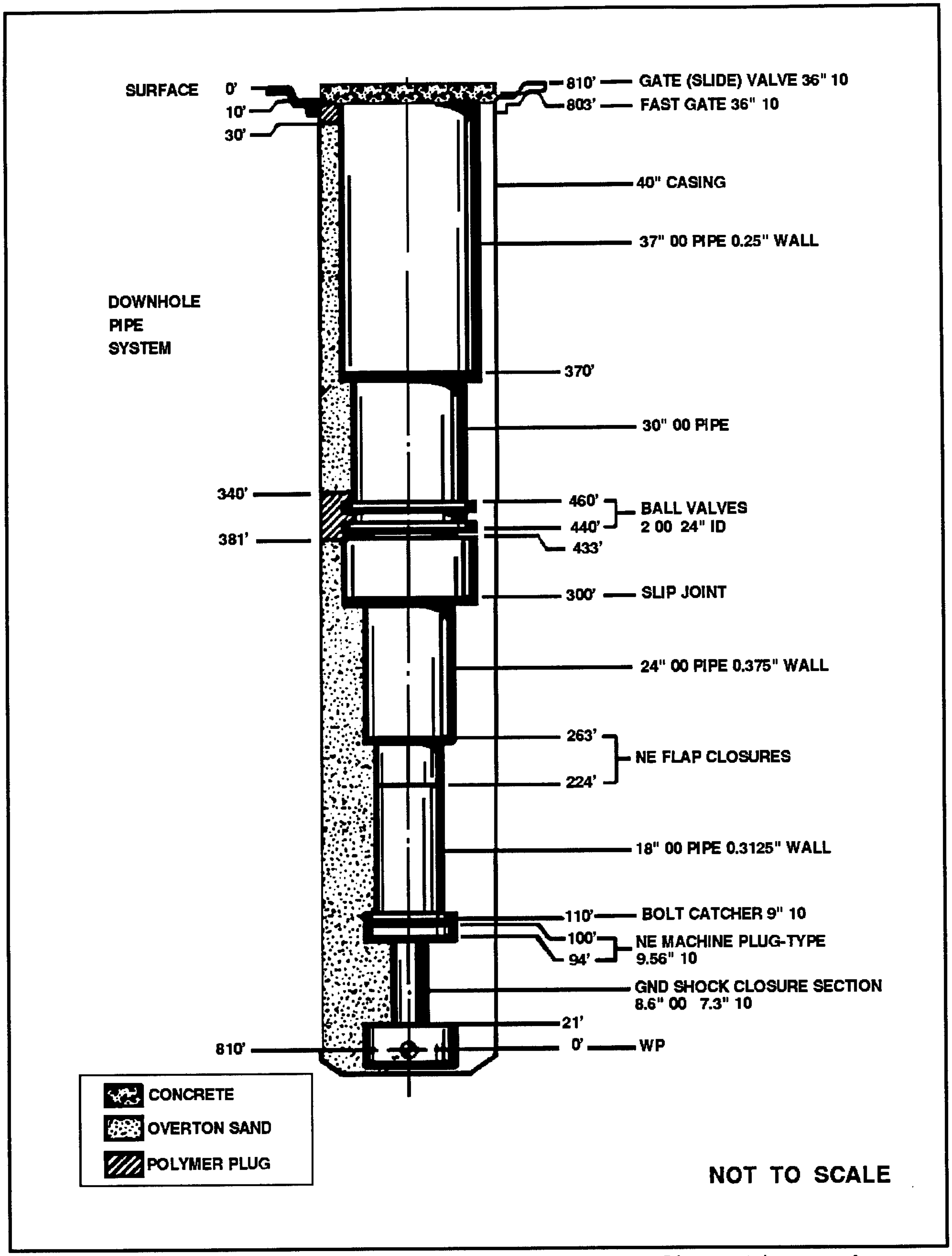

Figure 4-2. TAPESTRY event - test configuration and shaft stemming plan.

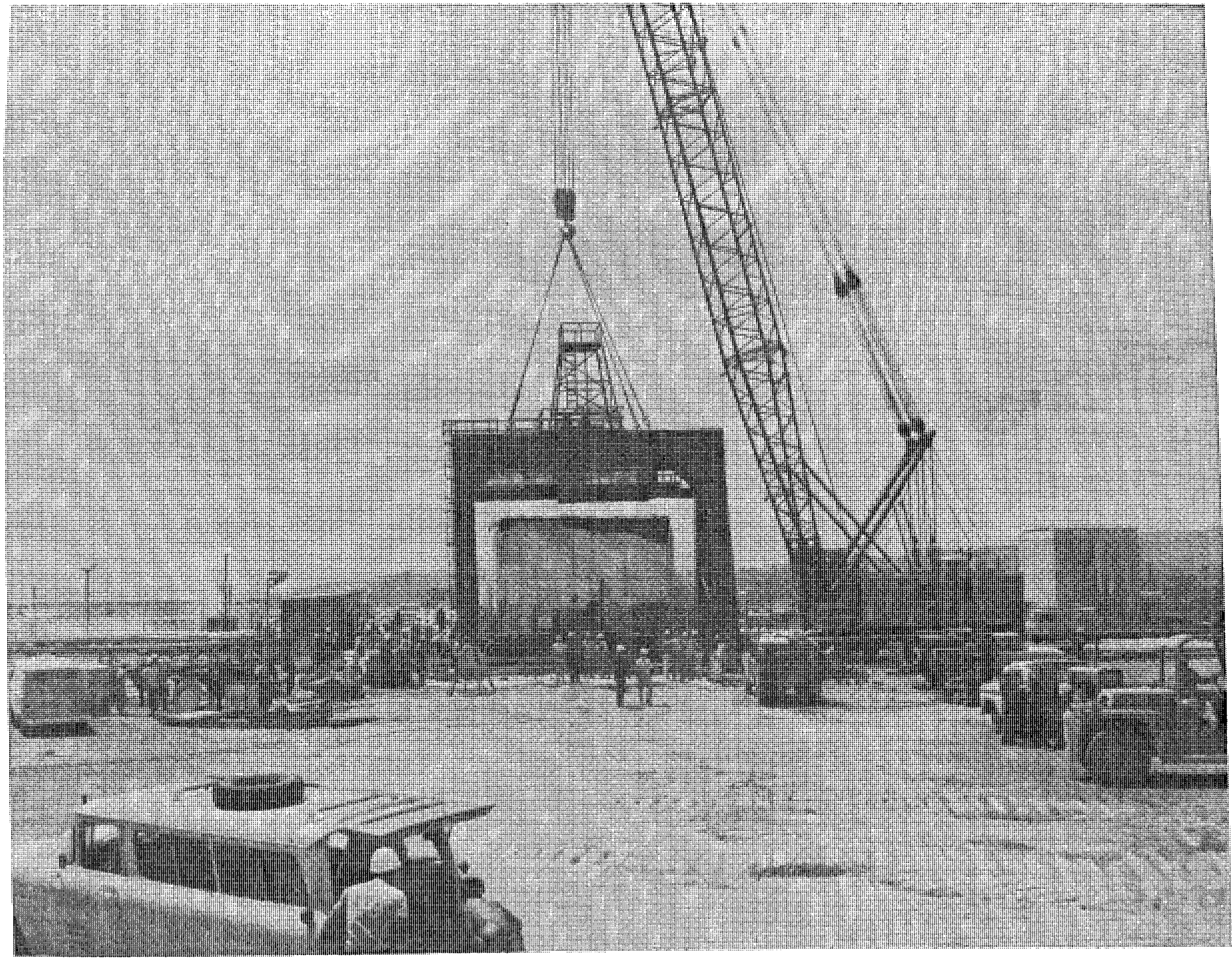

Figure 4-3. TAPESTRY event - A-frame support being positioned over Effects Room.

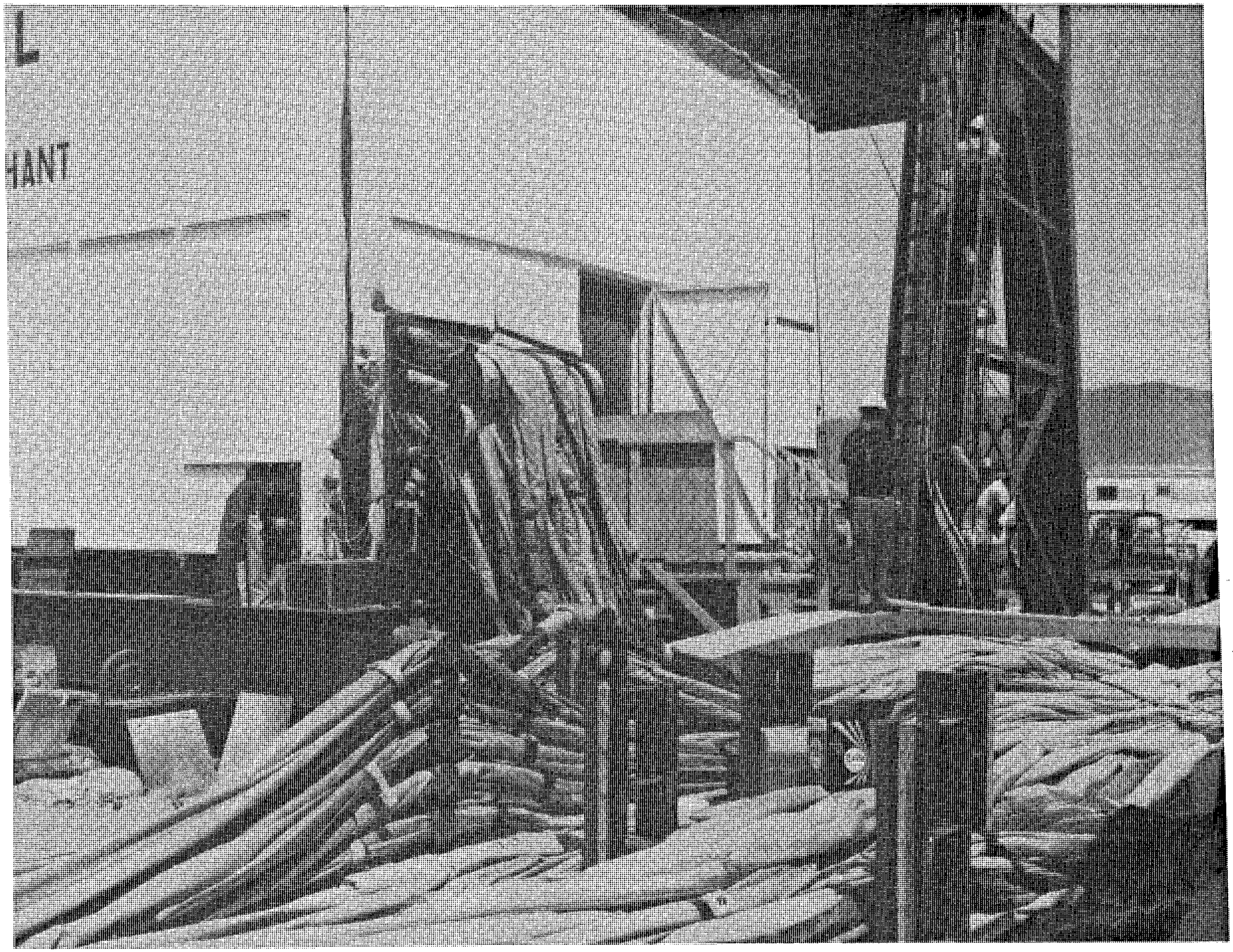

Figure 4-4. TAPESTRY event - cable from Effect Room connecting to data-recording trailers.

Laboratory (APL), CHAFF experiments; Ballistics Research Laboratory (BRL), basic structure response studies; Air Force Systems Command, Space Systems Division (SSD), space systems materials and components studies; Douglas Aircraft Corporation (DAC), Army systems experiments; Moleculon Research Corporation (MOLEC), diagnostic support; EG&G, data recording instrument support; TRW Systems, Incorporated (TRW), Ballistics Systems Division (BSD) pyrotechnic experiments; Picatinny Arsenal, Army pyrotechnic experiments; and Aerospace Corporation (AERO) BSD add-on experiments.

Sandia, LRL, and EG&G all conducted AEC-sponsored experiments involving instrument calibration, seismic studies, and firing system compatibility tests. They also provided photographic support.

Full-power full-frequency dry runs began on 30 April while final installation of equipment, cabling, and experiment setup continued.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were in accordance with AEC Manual Chapter 0524 and requirements of the responsible LRL Test Group Director or his representative. Radsafe provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimetry packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during dry runs. Party monitors were briefed regarding reentry, sample recovery, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in area reentry parties as needed. Radsafe personnel also were standing by at the Test Director's Barricade prior to detonation to perform surveys and provide emergency support as directed. Routine support included issuing anticontamination equipment and material, portable instruments, and dosimeters; operating area control check stations; and performing 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.

Remote telemetry radiation monitoring stations (RAMS) were positioned and operating at zero time at 19 surface locations. In addition, air sampling units (predecessors to the more mobile REECo-developed Model 102 high-volume air samplers) were located at 24 predetermined positions around the test area. There were also 16 remote area gas sampling units (RAGS) positioned around the test area. Table 4-1 lists the RAMS locations, Table 4-2 lists the air sampling unit locations, and Table 4-3 lists RAGS locations. Figure 4-5 shows these monitoring locations. Readout was recorded at CP-2 and transmitted via radio net to CP-1.

The Southwest Radiological Health Laboratory (SWRHL), operated by the U.S. Public Health Service (USPHS), was responsible for providing offsite surveillance. The USPHS operated air samplers at 102 stations and 24 stationary dose-rate recorders in offsite locations. Sixteen USPHS personnel were fielded for these surveillance activities.

D. Security Coverage.

Beginning at 0400 hours on 12 May 1966, muster and control stations for the area were established. All personnel entering or exiting the controlled area were required

Table 4-1. TAPESTRY event RAMS unit locations 12 May 1966.

STATION	LOCATION
1	0° azimuth, at 500 feet
2	45° azimuth, at 500 feet
3	90° azimuth, at 500 feet
4	135° azimuth, at 500 feet
5	180° azimuth, at 500 feet
6	225° azimuth, at 500 feet
7	270° azimuth, at 500 feet
8	315° azimuth, at 500 feet
9	At SGZ
10	SGZ Vent Pipe, before filter
11	SGZ Vent Pipe, after filter
12	0° azimuth, at 2,500 feet
13	45° azimuth, at 2,500 feet
14	90° azimuth, at 2,500 feet
15	135° azimuth, at 2,500 feet
16	180° azimuth, at 2,500 feet
17	225° azimuth, at 2,500 feet
18	270° azimuth, at 2,500 feet
19	315° azimuth, at 2,500 feet

Table 4-2. TAPESTRY event air sampling unit locations 12 May 1966.

STATION	LOCATION
1	45° azimuth, at 1,000 feet
2	90° azimuth, at 1,000 feet
3	135° azimuth, at 1,000 feet
4	180° azimuth, at 1,000 feet
5	225° azimuth, at 1,000 feet
6	270° azimuth, at 1,000 feet
7	315° azimuth, at 1,000 feet
8	360° azimuth, at 1,000 feet
9	22.5° azimuth, at 2,000 feet
10	45° azimuth, at 2,000 feet
11	67.5° azimuth, at 2,000 feet
12	90° azimuth, at 2,000 feet
13	112.5° azimuth, at 2,000 feet
14	135° azimuth, at 2,000 feet
15	157.5° azimuth, at 2,000 feet
16	180° azimuth, at 2,000 feet
17	202.5° azimuth, at 2,000 feet
18	225° azimuth, at 2,000 feet
19	247.5° azimuth, at 2,000 feet
20	270° azimuth, at 2,000 feet
21	292.5° azimuth, at 2,500 feet
22	315° azimuth, at 2,000 feet
23	337.5° azimuth, at 2,000 feet
24	360° azimuth, at 2,000 feet

Table 4-3. TAPESTRY event RAGS unit locations 12 May 1966.

STATION	LOCATION
1	0° azimuth, at 500 feet
2	45° azimuth, at 500 feet
3	90° azimuth, at 500 feet
4	135° azimuth, at 500 feet
5	180° azimuth, at 500 feet
6	225° azimuth, at 500 feet
7	270° azimuth, at 500 feet
8	315° azimuth, at 500 feet
9	SGZ vent pipe, before filter
10	SGZ vent pipe, before filter
11	SGZ vent pipe, before filter
12	SGZ vent pipe, before filter
13	SGZ vent pipe, after filter
14	SGZ vent pipe, after filter
15	SGZ vent pipe, after filter
16	SGZ vent pipe, after filter

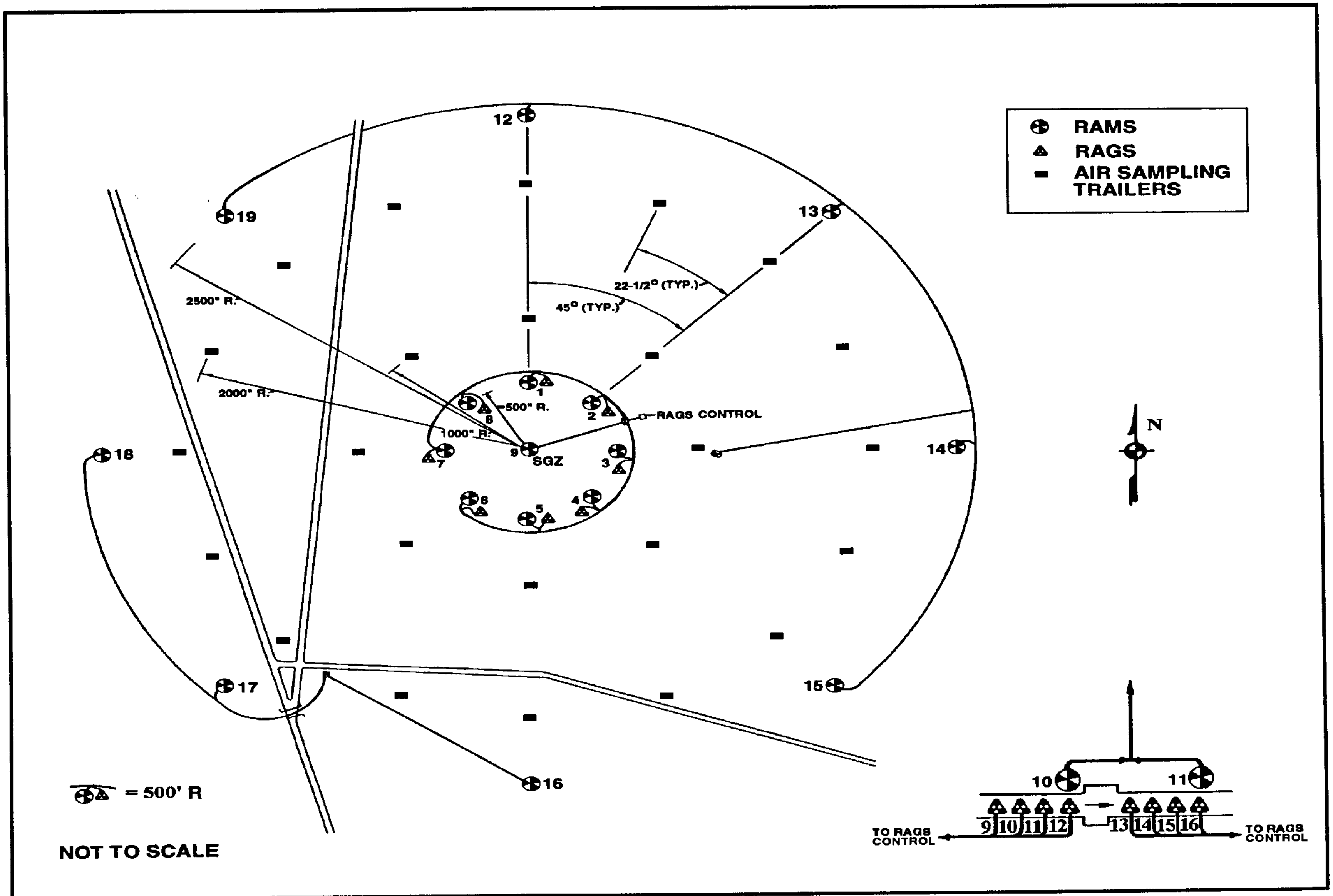

Figure 4-5. TAPESTRY event - surface RAMS, RAGS, and air sampling unit locations.

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 the use of roadblocks, access authorizations, and a Schedule of Events. Parties could enter the area only with the permission of the Test Group Director or Test Manager. Nonessential traffic was diverted around the controlled area.

Final sweep and clearance of the area began at H-5 hours to assure that contractor and agency personnel not associated with this event were out of the closed area. By H-4 hours all personnel, except arming and firing party members, were clear of the closed area.

E. Air Support.

The USPHS had a U6-A and Vegas VII aircraft on standby at ISAFB, and a Vegas II aircraft on standby in Las Vegas available for cloud tracking and cloud sampling missions.

4.3 EVENT-DAY ACTIVITIES.

4.3.1 Preshot Activities.

A readiness briefing for the Test Manager, Advisory Panel, and others was conducted in the CP-1 Conference Room at 0900 hours on 12 May. Conditions for the test were favorable and plans to detonate the device continued. By 0930 hours all persons except the arming and firing party were out of the test area and clear of the muster area. At 1030 hours the Test Manager gave the LRL Test Group Director permission to begin final arming of the device, and by 1200 hours all area activity was completed.

The TAPESTRY device was detonated at 1237 hours PDT on 12 May 1966.

4.3.2 Test Area Monitoring.

A prompt burst of radiation almost immediately after zero time measuring 45 R/h and then decreasing rapidly was detected on RAMS unit No. 9 located at SGZ. At H+1 minute RAMS unit No. 7

day. All other RAMS, except the SGZ and the units located before and after the ventline filter, read essentially background levels throughout the postshot drilling period. These units were operational until 17 June when telemetry was shut down at 2400 hours.

Two Air Force pilots and two USPHS monitors in a U-6A aircraft took off from ISAFB at 1130 hours. Their first pass was made over the SGZ area at 1240 hours at an elevation of 200 feet. Instruments recorded 3.5 mR/h. After crater subsidence at 1243 hours, the maximum reading was 4.0 mR/h recorded at 1245 hours and 200 feet elevation. There was no radioactive cloud formed, and no readings above background were encountered outside of a 100-yard circle around SGZ. The readings encountered were due to a point source. Aerial monitoring was completed at 1315 hours, and the mission was terminated at ISAFB at 1335 hours.

4.3.3 Initial Surface Radiation Surveys and Recovery Activities.

Initial reentry to the U2an area was conducted from the Test Director's Barricade (TDB) under the direction of the LRL Deputy Test Group Director. Three initial reentry teams were used to expedite movement of a large number of people into the area rapidly.

Initial survey team No. 1 departed from the TDB at 1249 hours on 12 May and proceeded to the trailer park. A radiation survey of the trailers and adjacent cables showed only background radiation levels (0.04 mR/h). This work was completed by 1305 hours.

The Crater Survey Team (team No. 2) departed from the TDB at 1252 hours and proceeded to trailer No. 48 where a survey at 1300 hours detected no radiation above background levels. At 1310 hours, the team surveyed the crater lip and recorded a reading of 10 mR/h. The cables leading from the crater read background levels. By 1305 hours, barricades were established and a hot line was operational.

The Effects Reentry Team (team No. 3) departed from the TDB at 1255 hours and proceeded to a location 500 feet south of SGZ where they established a staging area from which a survey of the Effects Building was made. By 1315 hours, the survey indicated the following conditions: (1) the building had moved about 12 feet then wedged against some object, snapping the pull mechanism; (2) cable cutters only partially severed the diagnostic and power cables to the building; (3) one of the walls of the building was deliberately pulled out as the building moved to facilitate access for film recovery; (4) the north side of the building was resting on the gate valve; and (5) the foot bridge (part of the building) was erect with a slight cant to the northeast.

By approximately 1340 hours, there began to be a noticeable seepage from the gate valve. Soon afterwards, the first film package was recovered from the crater. By 1405 hours, all personnel were in full-face masks because of an increase in radiation intensity levels. Wind velocity had also increased and readings at the cables and in the crater area were 2-5 mR/h. At this time the cable cutting crew began to sever the downhole cables and by 1435 hours the cable cutting and sealing operations were completed. By 1525 hours the cables to the Effects Building were cut, and at 1545 hours personnel dressed in full anticontamination clothing and using supplied air recovered some samples and film packages.

At 1600 hours personnel examined the gate valves to determine a possible method for obtaining a positive closure of the LOS pipe. Seepage from two valves continued and maximum readings at the valves were 10 R/h and 20 R/h respectively. At 1645 hours Explosives Team personnel had entered the Effects Building to assess whether any additional explosive hazards existed that were not present prior to shot time. None existed, and by 1730 hours their work was completed and the LRL Pinex experiment was recovered. The reading on the outside of the experiment canister was 500 mR/h.

By 1800 hours, a canopy had been set over the GZ area, the GZ casing where seepage was occurring was Cal-Sealed (sealed with a quick-drying cement), and some sample recoveries were being made. A survey of the crater at 1850 hours revealed a crack which was venting effluent. The radiation intensity level was 40 R/h in the crater hole. By 1915 hours, personnel had begun to seal the venting crack. The sealing operation was completed and a flexible line was installed. The LRL work party left the area by 2100 hours. At 2330 hours a tent was installed over a leaking valve at the end of the ventline. A check of the ventline at 0015 hours on 14 May revealed that the flow rate in the flexible line was 1,272 CFM. The reading before the filter was 180 mR/h, while after the filter the reading was only 8 mR/h.

4.4 POSTEVENT ACTIVITIES.

4.4.1 Post-Recovery Activities.

On 13 May personnel in anticontamination clothing and wearing full-faced masks entered the crater area to prepare for postshot drilling operations. Work was also started to prepare a site on which to place the Effects Building. Radiation readings in the GZ area varied between 30-200 mR/h, with the ventline at the lip of the crater reading between 30-100 mR/h open shield (i.e., beta plus gamma). By 1350 hours the air sampling trailers and RAMS numbers 11-17 were being secured. All ventline hookups to GZ, the ventline trailer, and to the cellar were accomplished by 2330 hours on 13 May in preparation for postshot drilling. A survey of the GZ area showed a maximum reading of 150 mR/h and no positive LEL or toxic gases.

On 16 May personnel continued to remove experiment components and samples from the Effects Building. However, this work was not completed until 24 May. On 18 May personnel began working to remove the A-Frame from the Effects Building. The Effects Building was then lifted from the LOS pipe and placed on a prepared pad in the crater. The next day the building was removed from the crater. The maximum reading in the area around the Effects Building was 0.1 mR/h. However, the crack on the north side of the crater was reading 140 mR/h.

On 20 May both ball valves were opened and the ventline connected to the open line. Radiation readings were 200 mR/h open shield and carbon monoxide (CO) levels measured 250 ppm. Readings on the ventline near the GZ casing and in the crater at GZ showed 9 mR/h and 5 mR/h, respectively. Personnel discovered that the ventline was broken in three places. When it was repaired, the reading in the crater decreased to 0.3 mR/h. The ventline monitoring report showed that effluent was continuously released until the end of June while drilling operations continued. Work continued in the GZ area in conjunction with the two-phase drilling operation. This work was not completed until

13 July. While maximum radiation readings during this period were below 10 mR/h, except for core samples or debris being removed, high toxic gas levels (CO) and explosive mixtures posed hazards periodically during this operation. Personnel donned masks during these periods and also at times when blowing dust posed problems.

4.4.2 Postevent Drilling.

Postshot drilling was carried out in two drilling phases. The first phase was to recover and analyze core samples. The second phase involved drilling, removing debris using high-pressure techniques ("hyvacing") from the GZ hole, and milling through the ball valves to determine why closures failed to function properly causing effluent to be released.

Drilling on postshot hole No. 1A began on 14 May at 1320 hours. The hole was directionally drilled to a total depth of 1,094 feet. Sampling began at 0110 hours on 16 May and was completed at 1010 hours that same day. Twenty-six core samples were taken with a maximum sample reading of 5.5 R/h. Postshot hole No. 1AS was sidetracked at 778 feet and drilled to a total depth of 1055 feet. Twenty-nine core samples were taken between 1635 hours and 2230 hours. Directional survey readings at 0200 hours on 17 May showed no toxic gases, no positive LEL levels, and no radiation above background levels. By 1042 hours the abandonment valve was closed and by 1500 hours the drill rig was moved out of the crater to the Decontamination Pad. The drill site facility was secured by 2300 hours on 18 May.

Second-phase drilling work started on 3 June when personnel began preparing a pad within the crater to position the drill rig. The drill rig was repositioned in the crater on 6 June and preparations for the second-phase drilling operation were started. A survey inside the GZ casing indicated greater than 3,000 ppm CO, 75 percent of the LEL, and radiation readings as high as 100 mR/h. During rig placement and set-up on 7 June, a downhole sample indicated 100 percent of the LEL, and CO levels as high as 40,000 ppm. The hyvacing operation to remove stemming material and debris and "clean out" the hole began at 0730 hours on 8 June and continued through 3 July. Milling operations through the two ball valves and picture taking of downhole work continued through early July. Radiation surveys during these operations indicated low radiation levels. The maximum reading on contact with debris from hyvacing was 200 mR/h on 1 July. Work ceased and rig shutdown began on 7 July. The last downhole pictures were taken on 11 July, and the area was secured on 13 July.

4.4.3 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were recorded in the monitors' logbook.

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

The construction areas were mandatory hard hat and foot protection areas (safety shoes, safety boots, AEC-issued miner's boots, or toe guards). All personnel on the initial area reentry teams were certified in the use of the Draeger self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus.

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials 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 0500 Series for the Nevada Test Site.[10]

3. Individual Safe Operating Procedures (by experimenter organization).

4. TAPESTRY Safety Regulations.

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[10] Applicable parts of the AEC SOP 0550 series were not superseded until 1968.

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 that had been approved by the LRL Safety Coordinator.

4.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 1237 hours on 12 May 1966. The SGZ RAMS read 45 R/h immediately after zero time due to a prompt burst of radiation. Except for those RAMS units located at SGZ and those positioned before and after the filter, all units read essentially background levels during the operational period. Some units were operated until 17 June when all telemetry was shut down.

Three reentry teams were fielded to conduct initial radiation surveys beginning at 1249 hours on 12 May. One team surveyed the trailers and cables, the second team surveyed the crater area, and the third team surveyed the Effects Building. Because the Effects Building was not pulled out of the SGZ area when cratering occurred, some damage was evident. Personnel making film and experiment recoveries in the SGZ area, around the cables, and around the Effects Building were dressed in anticontamination clothing and used supplied air while working in these areas.

Preparations for drilling operations, work to remove the Effects Building from the crater, postevent recoveries, and work on the LOS pipe components were ongoing while drilling continued. The maximum radiation reading was 250 mR/h open shield and the CO level was 250 ppm during this period except for the levels recorded when surveying debris and core samples.

Two postshot drill holes produced 26 and 29 core samples, respectively. The maximum reading on any one sample was 5.5 R/h. Drilling began on 14 May and was completed by 17 May. Radiation surveys showed background radiation levels. No toxic gases were detected, and no positive LEL levels were observed.

On 6 June the second-phase drilling operations began when the drilling rig was repositioned inside the crater. Work began on 7 June inside the GZ casing to remove stemming material and debris. Milling through the ball valves, along with hyvacing and downhole picture-taking work continued through 11 July. Downhole sampling on 7 June showed a maximum reading of 40,000 ppm CO and 100 percent of the LEL. The radiation reading inside the GZ casing on 6 June was 100 mR/h.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to TAPESTRY radex areas from 12 May to 11 July 1966. These totals are shown below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	2,189	300	1
DoD Participants	56	0	0

Minimum detectable gamma exposure with the NTS film dosimeter was 30 mR. Weekly film dosimeter exposure records from 11 May through 13 July 1966 and sample data records show that, in addition to the entries recorded on the Area Access Registers, nine additional DoD and DoD-contractor personnel received exposures that probably were the result of TAPESTRY event.

SECTION 5

AJAX EVENT

5.1 EVENT SUMMARY.

The AJAX event was an LRL-sponsored, weapons-related test conducted at 0400 hours PST on 11 November 1966, with a yield of less than 20 kilotons. The device was detonated in Area 9 (U9al) emplaced in a 48-inch diameter shaft at a depth of 782 feet (Figure 5-1). The purpose of the AJAX event was to test a nuclear device intended for a specific type of weapon system. The DoD-sponsored add-on experiment program NEAT RIBBON, that included five projects designed to study aspects of magnetic field measurements, energy coupling, and seismic measurements, was conducted during the AJAX event.

Surface collapse occurred at approximately H+10 minutes producing a subsidence crater about 400 feet in diameter and 75 feet deep. Two radioactive effluent releases were detected soon after the subsidence, one from the SGZ area at H+12 minutes lasting for approximately four minutes, and the other from the Red Shack at H+33 minutes also lasting for about four minutes. At 0240 hours on 15 November 1966 another radioactive effluent release was detected. The release lasted approximately five minutes. No radioactive effluent was detected offsite from any of these releases.

5.2 PREEVENT ACTIVITIES.

5.2.1 Responsibilities.

Safe conduct of all AJAX project activities in Area 9 was the responsibility of the LRL Test Group Director, subject to controls and procedures established by the AEC Test Manager. The AEC Test Manager was responsible for safety of onsite personnel and the public during the test.

Because LRL fielded the device, the LRL Test Group Director was responsible to the AEC Test Manager for radiological safety within a 4,000-foot radius of SGZ. This responsibility was in effect from the time the device was moved to the zero site until

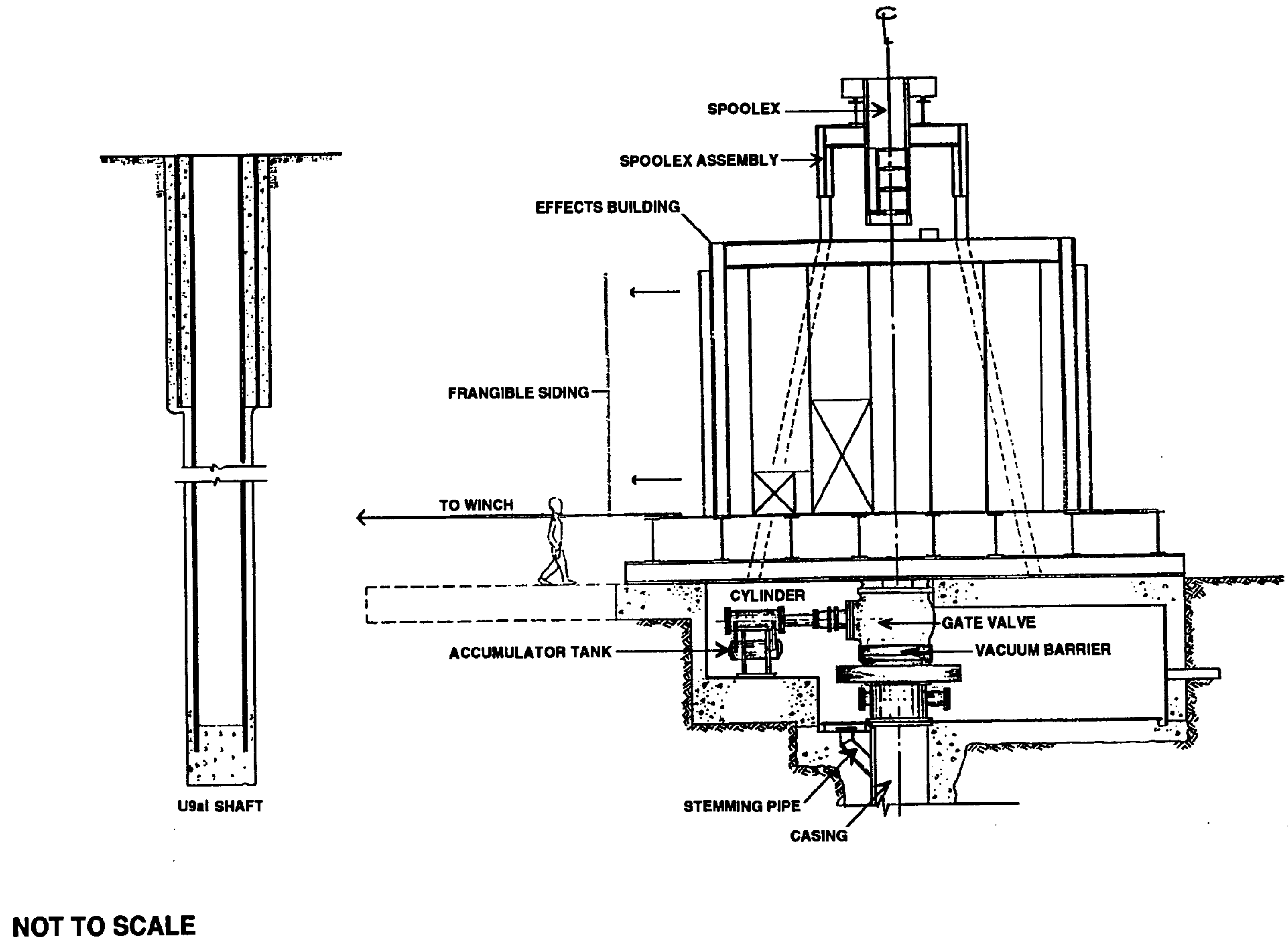

Figure 5-1. AJAX event - cross section of a portion of LOS pipe, effects building, and U9al shaft.

device detonation. After device detonation, the AEC Test Manager relieved the LRL Test Group Director of this responsibility.

Project agencies were responsible for designing, preparing, and installing experiments or delivering them to the installation contractor. After the event, each of these agencies was responsible for removing samples, analyzing instrument and sample data, and preparing project reports on their respective experimental results. Specifically, the DASA Test Group Director was responsible for informing the AEC Test Manager on the status of the NEAT RIBBON program.

REECo Radiological Safety Department (Radsafe) provided onsite radiological safety support services and was responsible to the LRL Test Group Director while the testing area was under his control. When the testing area was under the control of the AEC Test Manager, REECo Radsafe provided monitoring support, area control, and surveillance.

Firing circuits and timing signals were provided by EG&G. Responsibility for stemming and arming the device was assigned to LRL, EG&G, and Sandia.

5.2.2 Planning and Preparations.

A. Area Facilities Preparation and Construction.

AJAX event was conceived to study the feasibility of using an underground nuclear detonation with a vertical line-of-sight (VLOS) pipe to the surface to simulate a small surface electromagnetic pulse (EMP) source. A large iron converter was located just above the surface to create a gamma flux through reactions. This flux would produce scattering of electromagnetic radiation that ultimately would generate an EMP.

During the preparatory phase of AJAX event, when the down-hole dry run was completed, there was a four-month delay because of labor difficulties before event preparations resumed. During this period, the mechanical equipment was protected from deterioration. When preparations resumed, the final emplacement of the line-of-sight system required only nine days on a one shift/day basis. The mechanical closure systems, consisting of the fast gate valve and 24-inch ball valves, encompassed the latest design changes. These systems had previously undergone performance tests at LRL before installation. The Spoolex assembly, a housing that contained the five NEAT RIBBON and other experiments, was positioned directly above the concrete LOS pit (see Figure 5-1). This multi-experiment assembly provided an excellent method for fielding experiments that remained independent of the LOS system.

Experiments conducted under the NEAT RIBBON Program for the DoD included: Project 6.1, nuclear field tests of Weapons-Effects Buoy Systems (WEBS), U.S. Air Force Weapons Laboratory (AFWL); Project 6.3, energy coupling experiments and above-ground magnetic loop measurements, U.S. Army Research & Development Laboratories (ERDL); Project 6.4, magnetic field measurements, Harry Diamond Laboratories (HDL); Project 6.5, communications systems test and underground magnetic loop measurements, Bell Telephone Laboratories (BTL); and Project 6.6, far-field measurements, Denver Research Institute (DRI). This program provided, in part, a proof test of a simulation technique for creating a combined environment in which various electromagnetic pulse (EMP) experiments could be performed.

Experiments conducted for the AEC included several Stanford Research Institute (SRI) projects. Studies involved analysis of the AJAX EMP recording systems, evaluation of electric field detection and current sensors, and work on calibration and mapping signals. The U.S. Geological Survey (USGS) studied the response of aquifers to nuclear events, and SeaSpace Systems Incorporated (SEAS) conducted experiments using dual-diagnostic balloon arrays. Other experiments on seismic support studies for both the NTS and offsite projects were conducted by the Environmental Science Services Administration/Coast and Geodetic Survey (ESSA/C&GS).

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were in accordance with AEC Manual

Chapter 0524 and requirements of the responsible LRL Test Group Director or his representative. Radsafe provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimetry packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during dry runs. Party monitors were briefed regarding reentry, sample recovery, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in area reentry parties as needed. Radsafe personnel also were standing by at the Test Director's Barricade prior to detonation to perform surveys and provide emergency support as directed. Routine support included issuing anticontamination equipment and material, portable instruments, and dosimeters; operating area control check stations; and performing 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. <u>Telemetry and Air Sampling Support</u>.

Remote telemetry radiation monitoring stations were installed at 17 surface locations. In addition, air sampling units (predecessors to the more mobile REECo-developed Model 102 high-volume air samplers) were located at 24 predetermined positions around the test area. There were also eight remote area gas sampling units (RAGS) positioned around the test area. Table 5-1 lists the RAMS locations, Table 5-2 lists the air sampling unit locations, Table 5-3 lists RAGS locations. Figure 5-2 shows

Table 5-1. AJAX event RAMS unit locations 11 November 1966.

STATION	LOCATION
1	At SGZ
2	22.5° azimuth, at 750 feet
3	67.5° azimuth, at 750 feet
4	112.5° azimuth, at 750 feet
5	157.5° azimuth, at 750 feet
6	202.5° azimuth, at 750 feet
7	247.5° azimuth, at 750 feet
8	292.5° azimuth, at 750 feet
9	337.5° azimuth, at 750 feet
10	353° azimuth, at 2,500 feet
11	45° azimuth, at 2,500 feet
12	90° azimuth, at 2,500 feet
13	135° azimuth, at 2,500 feet
14	180° azimuth, at 2,500 feet
15	225° azimuth, at 2,500 feet
16	270° azimuth, at 2,500 feet
17	315° azimuth, at 2,500 feet

Table 5-2. AJAX event air sampling unit locations 11 November 1966.

STATION	LOCATION
1	22.5° azimuth, at 1,250 feet
2	67.5° azimuth, at 1,250 feet
3	112.5° azimuth, at 1,250 feet
4	157.5° azimuth, at 1,250 feet
5	202.5° azimuth, at 1,250 feet
6	247.5° azimuth, at 1,250 feet
7	292.5° azimuth, at 1,250 feet
8	337.5° azimuth, at 1,250 feet
9	22.5° azimuth, at 2,000 feet
10	45° azimuth, at 2,000 feet
11	67.5° azimuth, at 2,000 feet
12	90° azimuth, at 2,000 feet
13	112.5° azimuth, at 2,000 feet
14	135° azimuth, at 2,000 feet
15	157.5° azimuth, at 2,000 feet
16	180° azimuth, at 2,000 feet
17	202.5° azimuth, at 2,000 feet
18	225.5° azimuth, at 2,000 feet
19	247.5° azimuth, at 2,000 feet
20	270° azimuth, at 2,000 feet
21	292.5° azimuth, at 2,000 feet
22	315° azimuth, at 2,000 feet
23	337.5° azimuth, at 2,000 feet
24	360° azimuth, at 2,000 feet

Table 5-3. AJAX event RAGS unit locations 11 November 1966.

STATION	LOCATION
1	22.5° azimuth, at 750 feet
2	67.5° azimuth, at 750 feet
3	112.5° azimuth, at 750 feet
4	157.5° azimuth, at 750 feet
5	202.5° azimuth, at 750 feet
6	247.5° azimuth, at 750 feet
7	292.5° azimuth, at 750 feet
8	337.5° azimuth, at 750 feet

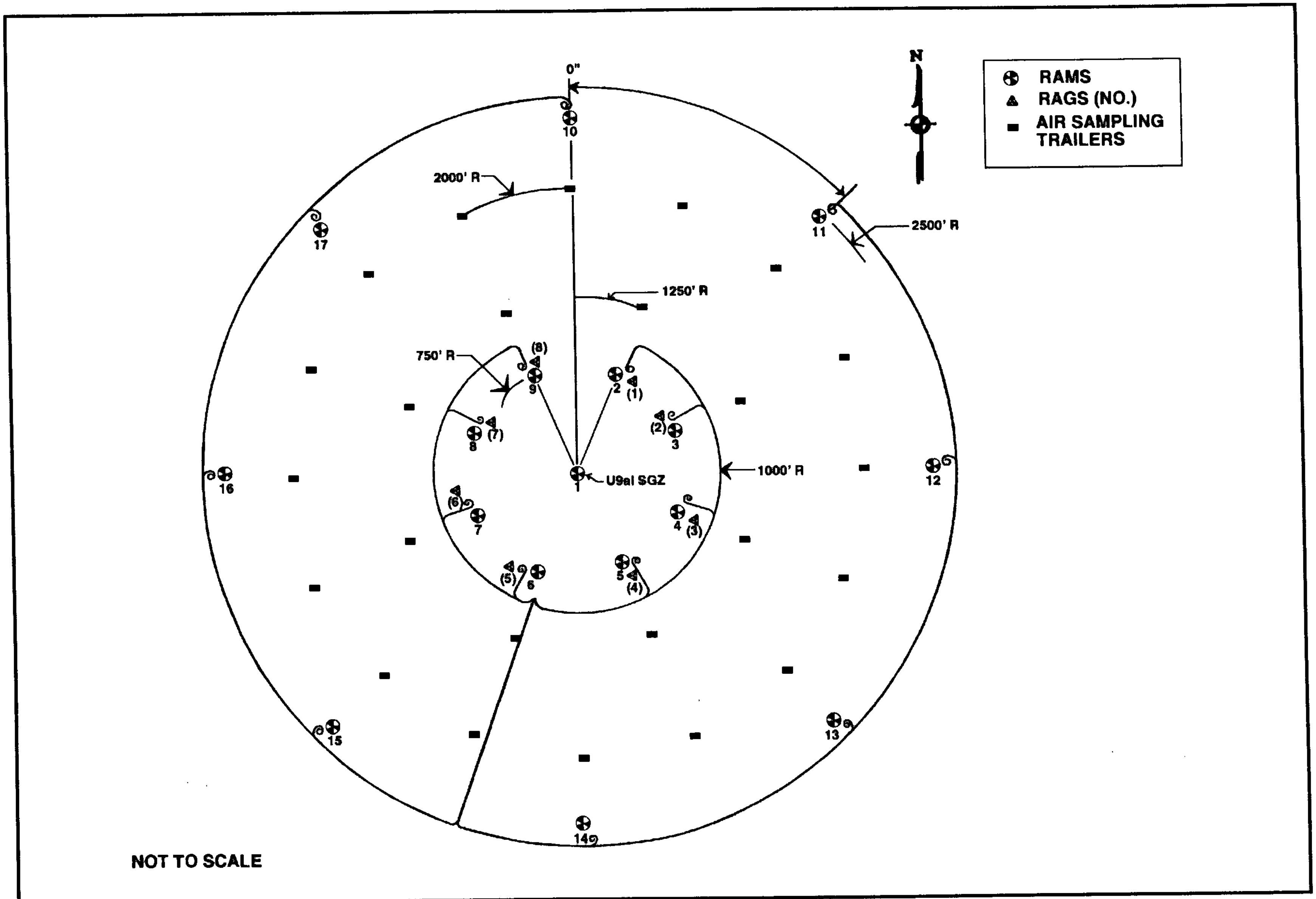

Figure 5-2. AJAX event - surface RAMS, RAGS, and air sampling unit locations.

these monitoring locations. Readout was recorded at CP-2 and reported by telephone to CP-1.

The Southwest Radiological Health Laboratory (SWRHL), operated by the U.S. Public Health Service (USPHS), was responsible for providing offsite surveillance. USPHS operated 94 air sampling stations and 21 stationary dose-rate recorders in offsite locations. Fourteen USPHS personnel were fielded for offsite surveillance activities.

D. Security Coverage.

Beginning at 1600 hours on 10 November 1966, muster and control stations for the area were established. 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 the use of roadblocks, access authorizations, and a Schedule of Events. Parties could enter the area only with the permission of the Test Group Director or Test Manager. Nonessential traffic was diverted around the controlled area.

Final sweep and clearance of the area began at H-7 hours to assure that contractor and agency personnel not associated with this event were out of the closed area. By H-4 hours all personnel, except arming and firing party members, were cleared from the closed area.

E. Air Support.

The Air Force Special Weapons Center (AFSWC), Detachment 1, located at Indian Springs Air Force Base (ISAFB), provided two helicopters and four fixed-wing aircraft with crews to perform any aerial monitoring or sampling as required. The USPHS had one Turbo Beech aircraft at the NTS and one standing by in Las Vegas for cloud tracking missions. The USPHS cloud tracking team was on standby at ISAFB.

5.3 EVENT-DAY ACTIVITIES.

5.3.1 Preshot Activities.

A readiness briefing for the Test Manager, Advisory Panel and others was conducted in the CP-1 Conference Room at 0200 hours on 11 November. Conditions for the test were favorable and plans to detonate the device continued. By this time, all persons except the arming and firing party were out of the test area and clear of the muster area. Permission was granted to arm the device. By 0300 hours all area activity was completed. The AJAX device was detonated at 0400 hours PST on 11 November 1966. Surface collapse occurred at H+10 minutes producing a subsidence crater.

5.3.2 Test Area Monitoring

Telemetry measurements beginning at 0401 hours showed the maximum reading of 300 mR/h on both the 22.5° and 67.5° azimuths on the 750-foot arc. Two small radioactive releases were detected by RAMS units following detonation. The first release from SGZ, which lasted for four minutes, was detected at approximately H+12 minutes on the 22.5° azimuth on the 750-foot arc. Then the cloud passed over RAMS unit No. 14 on the 2,500-foot arc on the 180° azimuth at approximately H+24 minutes where the reading was 3 mR/h. A second release from the Red Shack was also detected at RAMS unit No. 14 at H+33 minutes. By H+30 minutes all RAMS on the 2,500-foot arc were indicating background radiation levels, and by H+8 hours all RAMS on the 750-foot arc were indicating background radiation levels. All telemetry was shut down at 1600 hours on 14 November.

5.3.3 Initial Surface Radiation Surveys and Recovery Activities.

At 0545 hours on 11 November 1966, initial survey teams departed from the Test Director's Barricade wearing full-face masks (for protection against potentially radioactive dust) and anticontamination clothing. By 0630 hours initial surveys of the trailer park and general crater areas were completed. The maximum reading was 190 mR/h on the cables near the splice rack except for the area about 20 feet from the suspended experiment package (i.e., the Spoolex assembly housing the NEAT RIBBON and other experiments) where the reading was 500 mR/h. At 0710 hours, after all electrical power to SGZ was shut off, the survey party entered the crater. Personnel made a visual damage inspection and began preparations for experiment recoveries. By 0810 hours LRL personnel began recovery operations for some of the experiment package; the reading at the southwest lip of the crater was 15 mR/h. Simultaneously, other experiments were recovered, surveyed and loaded onto a truck for transport to an LRL facility on the NTS for further monitoring. Sample and package recovery work continued throughout the day. At 1300 hours a survey at the Red Shack indicated 3.0 mR/h, but later surveying showed readings had decreased to slightly above background radiation levels. By 1700 hours initial recoveries were completed; a survey showed readings just above background levels on the lip of the crater; and the recovery teams left the area.

5.4 POSTEVENT ACTIVITIES.

5.4.1 Post-Recovery Activities.

Crater recoveries resumed on 14 November while preparations for postshot drilling began. At 0810 hours the operating engineers began removing a large crane (used to recover large, heavy equipment and experiment packages) from the crater area to facilitate the operations for setting up postshot drilling equipment. Each piece of equipment recovered from the GZ casing and the area around SGZ was documented before being removed from the area. Radiation surveys showed a maximum reading of 0.15 mR/h at the lip of the crater.

On that same day, the RadSafe base station was moved to the trailer park and cable run areas on the 750-foot perimeter fence southwest of SGZ to facilitate the recovery operation when postshot drilling began. This reestablished base station, termed the Crater Reentry Station in the monitor's logbook, was now the checkpoint where all crater reentries were recorded, and recoveries were monitored and logged when equipment or experiment packages were removed from the crater area.

This base station was operational at 0800 hours on 15 November. At that time, personnel dressed in anticontamination clothing and wearing respirators entered the crater and began work to remove experiments from the concrete pit (surrounding the LOS pipe and experiments). On 16 November at 1000 hours LRL and DASA personnel brought in equipment to remove the Spoolex assembly. By 1500 hours they had removed the lead shields from the Spoolex assembly and moved the entire unit out of the concrete pit, exposing the fast gate valve. The maximum reading was 70 mR/h at the fast gate valve while the Spoolex assembly read 30 mR/h. By 1545 hours the Spoolex assembly had been removed from the crater, secured, and stored in the area above the crater. Experimenters continued to remove equipment from the crater area from 17 November through 29 November (i.e., simultaneously with drill-back and core sampling operations). All equipment and recovered materials were documented, and each item was monitored prior to being removed from the crater area. Radiation readings were typically less than 0.5 mR/h.

On 30 November LRL personnel, wearing breathing apparatus, began preparations for taking pictures down the LOS pipe using a camera suspended by a cable from a boom device. When workers removed the cover plate from the LOS pipe, the carbon monoxide (CO) level was 2,000 ppm. Within ten minutes, the CO level dropped to 50-100 ppm. Radiation readings were at background levels. This work was completed by 1500 hours on 1 December, and the area was secured.

5.4.2 Postevent Drilling.

Beginning at 0800 hours on 14 November, workers opened the abandonment valve on the predrilled hole and began preparing for postshot drilling operations. No increase in radiation was detected. Air sampling equipment was placed at positions approximately 100 feet from the drill rig at the four compass points. A RAM probe was placed on the ventline between the filters and the blowers with the readout recorder and alarm in the Radsafe monitoring trailer.

Drilling began at 1605 hours on 14 November at postshot (PS) hole No. 1A. By 1700 hours workers had drilled through the shoe (concrete plug that sealed the partially drilled hole). There was no detectable radiation, no toxic gases, and no positive LEL levels. At 1830 hours, circulation was lost (i.e., the circulating mud/water mixture did not return to the surface but remained underground filling up cracks and fissures) at 204 feet. After the drill was removed from the hole, a swipe taken of the shaker screen showed no alpha contamination.

On 15 November as drilling continued in preparation for core sampling, all personnel working in the cellar were wearing full-face masks. At 0240 hours, a five-minute release of noble gases occurred from the ventline into the cellar after the head gasket was removed. The radiation reading was 110 mR/h in the cellar. By 1050 hours the readings were 0.15 mR/h on both the drill rig platform and in the cellar. Coring on PS hole No. 1A began at 1922 hours at a depth of approximately 1,000 feet. Thirty samples were taken over a seven-hour period. The maximum reading on a core sample was 4 R/h.

Three sidetrack holes were drilled between 0505 hours on 16 November and 0115 hours on 19 November. On 16 November PS No. 1AS was sidetracked at 575 feet. Coring began at 1245 hours and was completed by 1932 hours. Nineteen core samples were taken with the maximum reading on any sample being 4 R/h. Radiation levels on the drilling platform were 0.6 mR/h. The second hole, No. 1ASS, sidetracked at 697 feet, was sampled beginning at 0732 hours on 17 November. Thirty-six core samples were taken; the maximum reading was 12 R/h. This work was completed by 1412 hours. The third sidetrack hole, PS No. 1ASSS, sidetracked at 291 feet and drilled to a depth of 1,002 feet, was core sampled beginning at 2230 hours on 18 November. Seventeen core samples were taken over approximately a three-hour period. The maximum reading on a sample was 5.5 R/h.

The abandonment valve was closed at 0720 hours on 19 November. The drill rig was removed, and equipment was decontaminated during the day. Work was completed and the postshot drilling area was secured by 1630 hours.

5.4.3 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were recorded in the monitors' logbook.

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

The construction areas were mandatory hard hat and foot protection areas (safety shoes, safety boots, AEC-issued miner's boots, or toe guards). All personnel on the initial reentry teams were certified in the use of the Draeger self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus.

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials 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 0500 Series for the Nevada Test Site.[11]

3. Individual Safe Operating Procedures (by experimenter organization).

4. AJAX 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 that had been approved by the LRL Safety Coordinator.

5.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 0401 hours on 11 November 1966. During the period telemetry was operational, the maximum reading detected was 300 mR/h on both the 22.5° and 67.5° azimuths on the 750-foot arc at 0401 hours. Two radioactive releases were detected by RAMS units after detonation. All telemetry was shut down at 1600 hours on 14 November.

The initial reentry survey teams entered the area at 0545 hours on 11 November and completed the surveys of the trailer park and general crater areas by 0630 hours. The reading at the cables near the splice rack was 190 mR/h. This was the maximum reading detected except for the area 20 feet from the Spoolex assembly

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[11] Applicable parts of the AEC NTSO SOP 0550 series were not superseded until 1968.

housing that read 500 mR/h. Initial experiment package recovery work continued throughout the day. By 1700 hours recovery teams completed their work and left the area.

While crater recoveries resumed and preparations for postshot drilling continued on 14 November, the RadSafe base station was relocated to the trailer park on the 750-foot perimeter fence southwest of SGZ. This was done to monitor and record recoveries without interfering with postshot drilling operations. Experiment recoveries and equipment removal continued through 29 November. Radiation levels were typically less than 0.5 mR/h except at the fast gate valve and Spoolex assembly that read 70 mR/h and 30 mR/h respectively. Downhole picture-taking began on 30 November and was completed the next day. Carbon monoxide levels were 2,000 ppm when workers removed the cover plate on the LOS pipe to begin taking pictures downhole. The CO level quickly decreased to 50-100 ppm, and radiation readings were at background levels. This work was completed, and the area was secured by 1500 hours on 1 December.

Postshot drilling began at 1605 hours on 14 November. A five-minute release of noble gases into the cellar occurred at 0240 hours on 15 November when the head gasket was removed; a reading of 110 mR/h was recorded in the cellar. In addition to the initial drill hole, three sidetrack holes were drilled. A total of 102 core samples were taken during postshot drilling operations with a maximum sample reading of 12 R/h recorded on a sample from PS No. 1ASS. Sampling was completed on 19 November, and the abandonment valve was closed at 0720 hours. No positive LEL level or toxic gases were noted during these operations.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to AJAX radex areas from 11 November to 19 November 1966. These totals are shown below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	571	240	4
DoD Participants	21	30	3

The minimum detectable gamma exposure with the NTS film dosimeter was 30 mR. Daily film dosimeter exposure records from 14 November to 29 November 1966 and sample data records show that, in addition to the entries recorded on the Area Access Registers, eight additional DoD and DoD-contractor personnel received exposures that probably were the result of AJAX event.

SECTION 6

CYPRESS EVENT

6.1 EVENT SUMMARY

The CYPRESS event was a Sandia Laboratories (SL)-sponsored weapons-effects test, conducted at 0818 hours PST on 12 February 1969, with a yield of less than 20 kilotons. The device, provided by Lawrence Radiation Laboratory (LRL), was detonated in the U12g.09 drift of G tunnel complex (Figure 6-1) emplaced 6,190 feet from the tunnel portal at a vertical depth of burial at the working point (WP) of 1,350 feet. The purpose of the event was to determine the vulnerability of electronics and weapons system components to nuclear radiation. In addition, DoD-sponsored projects involving seismic experiments and nuclear systems studies were also conducted.

No radiation release occurred from this detonation or during postshot activities. Geophones indicated rock falls in the cavity started at zero time and continued intermittently until cavity collapse at H plus two hours, fifty minutes.

6.2 PREEVENT ACTIVITIES

6.2.1 Responsibilities

Safe conduct of all CYPRESS project activities in Area 12 was the responsibility of the Sandia Test Group Director. Responsibilities of the AEC and its contractor personnel were in accordance with established AEC-DoD agreements or were the subject of separate action between Field Command/DASA and the AEC Nevada Operations Office. The AEC Test Manager was responsible for safety of onsite personnel and the public during the test.

Project agencies were responsible for designing, preparing, and installing experiments or delivering them to the installation contractor. After the event, each of these agencies was responsible for removing samples, analyzing instrument and sample data, and preparing project reports on their respective experimental results. Specifically, the DASA Test Group Director was responsible for coordinating the DoD experiments with the Sandia

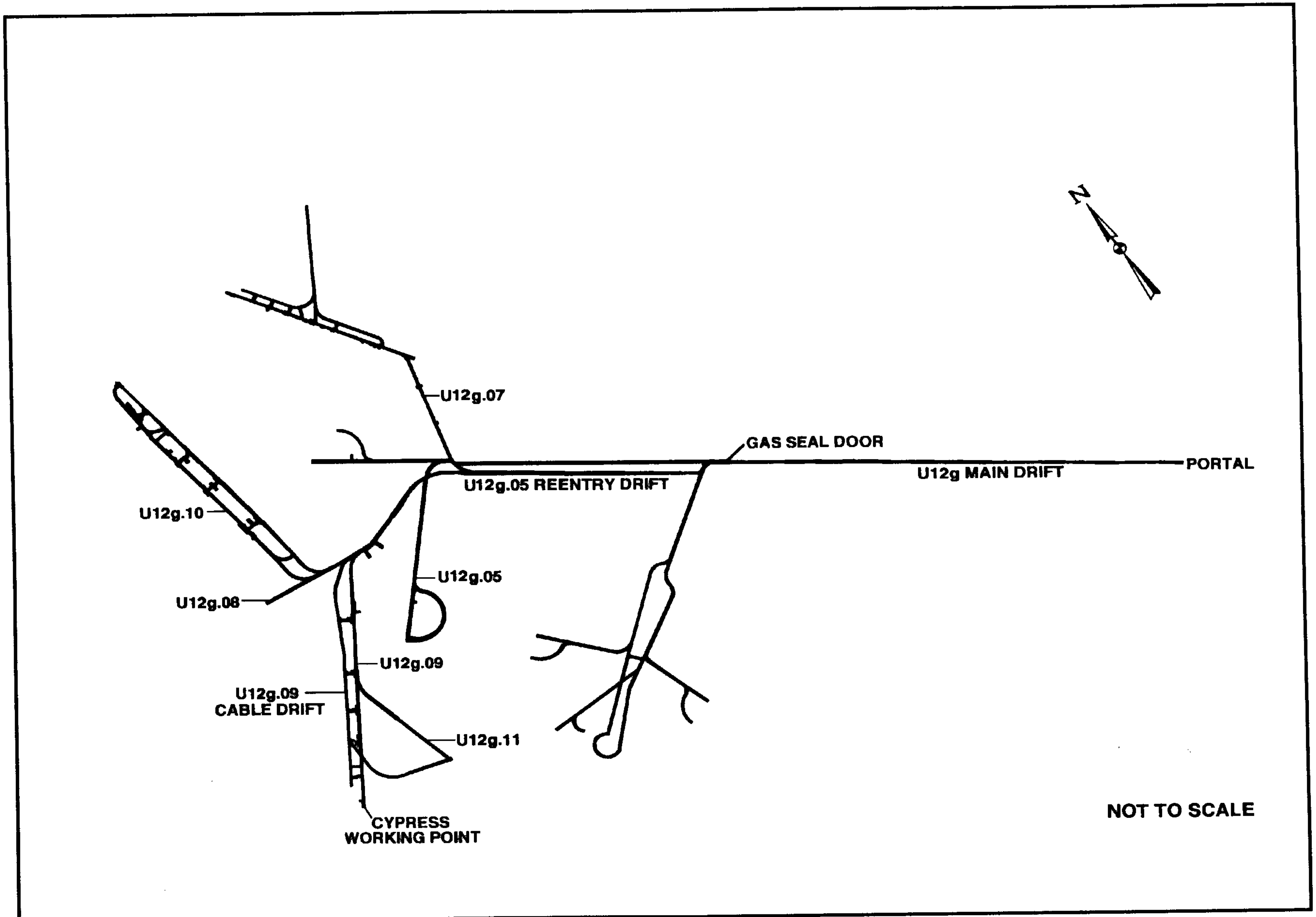

Figure 6-1. CYPRESS event - tunnel layout.

Test Group Director and informing the AEC Test Manager of the status of the DoD program.

Because LRL fielded the device, the LRL Test Group Director was responsible to the AEC Test Manager for radiological safety within a 6,000-foot radius of surface ground zero (SGZ). This responsibility was in effect from the time the device was moved to the zero site until device detonation. After device detonation, the AEC Test Manager relieved the LRL Test Group Director of this responsibility according to the provisions of the NTS SOP 0524 and issued the responsibility to the Sandia Test Group Director.

REECo Radiological Safety Department (Radsafe) provided onsite radiological safety support services and was responsible to the Sandia Test Group Director while the testing area was under his control. When the testing area was under the control of the AEC Test Manager, REECo Radsafe provided monitoring support, area control, and surveillance.

Firing circuits and timing signals were provided by EG&G. The responsibility for stemming the device was assigned to Sandia, and LRL, while LRL was assigned to arm the device.

6.2.2 Planning and Preparations.

A. Area Facilities Preparation and Construction.

The CYPRESS event, located in the U12g.09 drift at the southern end of Rainier Mesa, was physically arranged so that the downhole cable plant and Mesa Trailer Park (Figure 6-2) could serve other events in addition to CYPRESS. This tunnel event was the first one where the effects diagnostics were located on the mesa. Therefore, the cables had to be placed in a vertical cable hole necessitating that changes be made in the type of shielding around the cable bundles and the type of insulated cable used. Portal area facilities (i.e., assembly buildings and trailer parks) were also arranged to serve other events.

The 1500-foot CYPRESS drift was mined beginning in July 1967 and completed in July 1968. The drift was excavated in the same geological type of tunnel bed formation as the MIDI MIST and DOOR MIST events, while the design was

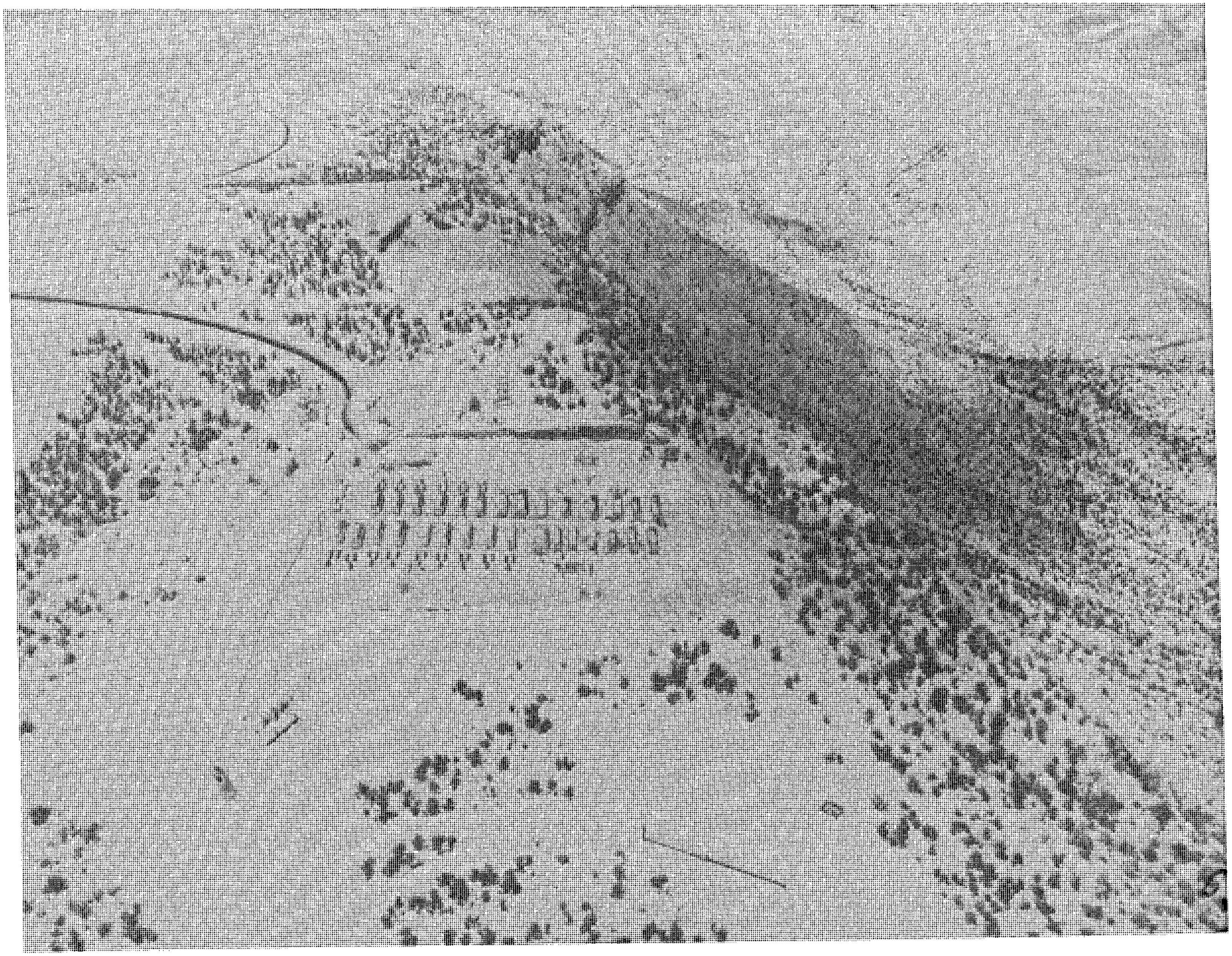

Figure 6-2. CYPRESS event - Mesa Trailer Park.

based on the experience gained from MIDI MIST, DORSAL FIN, and HUDSON SEAL events. The basic containment for this event relied on closure and sealing of the drift by the ground shock generated by the nuclear detonation.

The CYPRESS line-of-sight (LOS) pipe was 1,100 feet long, incorporating five experiment stations (ES) at approximately 195, 410, 550, 778, and 1,100 feet. The pipe diverged from 12 inches to 67 inches in diameter at 405 feet, near the end of the stemmed portion of the tunnel. Closure enhancement was increased by stemming the LOS pipe to approximately 410 feet. The stemming configuration closely followed that of the GUMDROP event with the use of ground-matching grout in the first 100 feet to reduce cavity extension along the LOS drift. The remainder of the stemming consisted of a low-strength grout (i.e., low-velocity sand or weak grout) with voids in the stemming at 100 to 120 feet, 168 to 198 feet, and 245 to 275 feet from the WP (Figure 6-3). These voids were expected to disrupt any possible leakage path along the tunnel and vacuum pipe. The Fast Gates, located at approximately 352 and 360 feet, protected the experiment stations from shrapnel.

The backup containment system, located at 388 feet, consisted of a specially designed concrete plug (to seal the tunnel) in conjunction with a gravity-fall steel wedge assembly that sealed the LOS pipe. The Gas Seal Valve and concrete plug were designed to contain peak overpressures of 1,000 psi and temperatures of 1,000°F. Finally, should these other systems fail, containment was provided by a 1,000 psi concrete Overburden Plug (OBP) in both the LOS and Cable drifts as well as a 75 psi Gas Seal Door (GSD) in the main U12g tunnel.

The experiment stations contained both DoD- and AEC-sponsored experiments. Sandia Laboratories conducted both effects and diagnostics studies for the AEC. These tests used nearly 70 percent of the allotted exposure area. The DoD agency experimenters, LRL, and Los Alamos Scientific Laboratory (LASL) used a combined 30 percent of the exposure area.

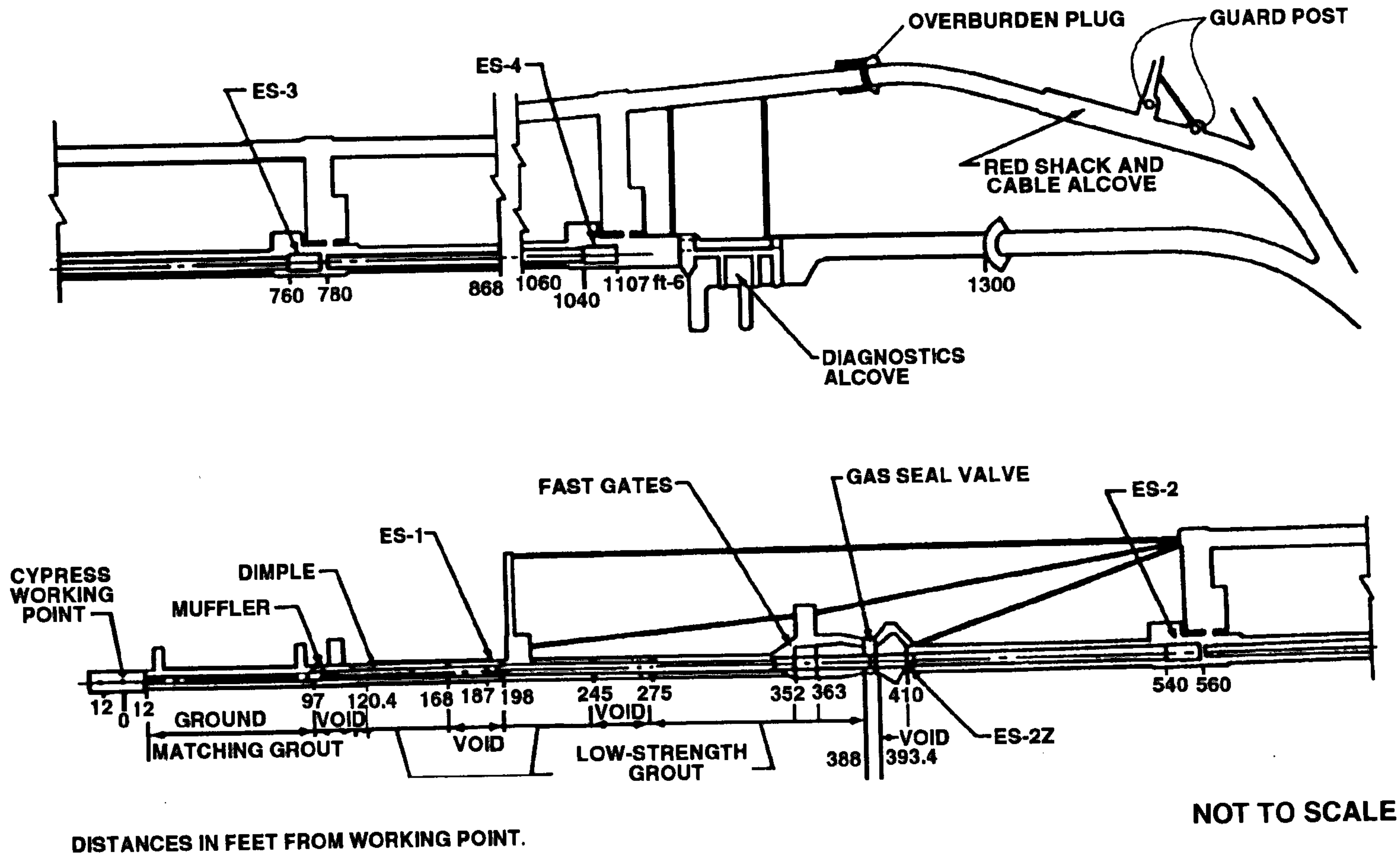

Figure 6-3. CYPRESS event - tunnel and pipe layout.

The DoD-sponsored experiments, coordinated through DASA, were conducted by the following agencies or contractors: Air Force Weapons Laboratory (AFWL), conducted advanced ballistics reentry systems studies; Kaman Nuclear (KAMAN) conducted Spartan tests; Lockheed Missiles & Space Company (LMSC) conducted MK3 antenna studies; and both Systems, Science and Software, Incorporated (SSS) and General Research Corporation (GRC) conducted x ray-related studies. Additional experiments were conducted by Aerospace Corporation; Effects Technology, Incorporated; and Redstone Arsenal.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were in accordance with AEC Manual Chapter 0524 and requirements of the responsible Sandia Test Group Director or his representative. Radsafe provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimetry packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during dry runs. Party monitors were briefed regarding reentry, sample recovery, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in area reentry parties as needed. Radsafe personnel also were standing by at the Test Director's Barricade prior to detonation to perform surveys and provide emergency support as directed. Routine support included issuing anticontamination equipment and material, portable instruments, and dosimeters; operating area control check stations; and performing 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.

In addition to the permanent RAMS units, 47 temporary units provided surface and underground coverage for CYPRESS. In addition, four air samplers, two at the portal and two near the cable hole were operational. Table 6-1 and Table 6-2 list the locations of both surface and underground RAMS respectively. Figure 6-4 and Figure 6-5 show the locations of the surface and underground RAMS respectively. All RAMS were installed a minimum of five days prior to scheduled device detonation. Telemetry readout was recorded manually at CP-2 and transmitted via telephone to CP-1.

The Southwest Radiological Health Laboratory (SWRHL), operated by the U.S. Public Health Service (USPHS) was responsible for providing offsite surveillance. The USPHS operated air samplers at 50 stations in offsite locations. Nine USPHS personnel were fielded for these surveillance activities.

D. Security Coverage.

Beginning at 1600 hours on 11 February 1969, muster and control stations for the area were established. 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 the use of roadblocks, access authorizations, and a Schedule of Events. Parties could enter the area only with the permission of the Test Group Director or Test Manager. Nonessential traffic was diverted around the controlled area.

Table 6-1. CYPRESS event RAMS unit locations 12 February 1969.

SURFACE

STATION	LOCATION
From the U12g Portal unless otherwise indicated:	
1	At the Portal
2	156 feet at 160° azimuth on the filter system[12]
3	156 feet at 160° azimuth on the filter system[12]
4	156 feet at 160° azimuth on the filter system[12]
5	280 feet at 31° azimuth
6	530 feet at 58° azimuth
7	500 feet at 105° azimuth
8	520 feet at 158° azimuth
9	225 feet at 245° azimuth
10	255 feet at 335° azimuth
11	1,375 feet at 15° azimuth
12	1,445 feet at 81° azimuth
13	1,235 feet at 195° azimuth
14	2,690 feet at 288° azimuth
15	164 feet at 354° azimuth from cable hole #1
16	4,250 feet at 280° azimuth[12]
17	4,545 feet at 293° azimuth[12]
18	4,400 feet at 301° azimuth[12]
From Cable Hole Number 2:	
19	At cable hole number 2
20	300 feet at 48° azimuth
21	300 feet at 120° azimuth
22	240 feet at 190° azimuth
23	240 feet at 285° azimuth
From SGZ:	
24	700 feet at 45° azimuth
25	250 feet at 180° azimuth[12]
26	700 feet at 315° azimuth

[12] Since documentation is not consistent, it is possible that these locations were changed shortly before event detonation.

Table 6-2. CYPRESS event RAMS unit locations 12 February 1969.

UNDERGROUND

STATION	LOCATION
27	800 feet into the U12g.10 LOS drift
28	300 feet into the U12g.10 cable drift
29	949 feet into the U12g.09 LOS drift
30	920 feet into the U12g.09 cable drift
31	721 feet into the U12g.09 LOS drift
32	520 feet into the U12g.09 cable drift
33	400 feet into the U12g.09 LOS drift
34	275 feet into the U12g.09 LOS drift
35	300 feet into the U12g.09 cable drift
35 AT[13]	260 feet into the U12g.09 cable drift
36	85 feet into the U12g.09 cable drift
37	180 feet into the U12g.09 LOS drift
37 AT[13]	100 feet into the U12g.09 LOS drift
38	550 feet into the U12g.07 drift
39	1,300 feet into the U12g reentry drift
40	150 feet into the U12g.01 drift
From the U12g portal:	
41	2,500 feet into the U12g main drift
41 AT[13]	2,495 feet into the U12g main drift
42	2,375 feet into the U12g main drift
43	1,200 feet into the U12g main drift
44	50 feet into the U12g main drift

[13] AT - Probe buried in tunnel invert (floor) or sidewall.

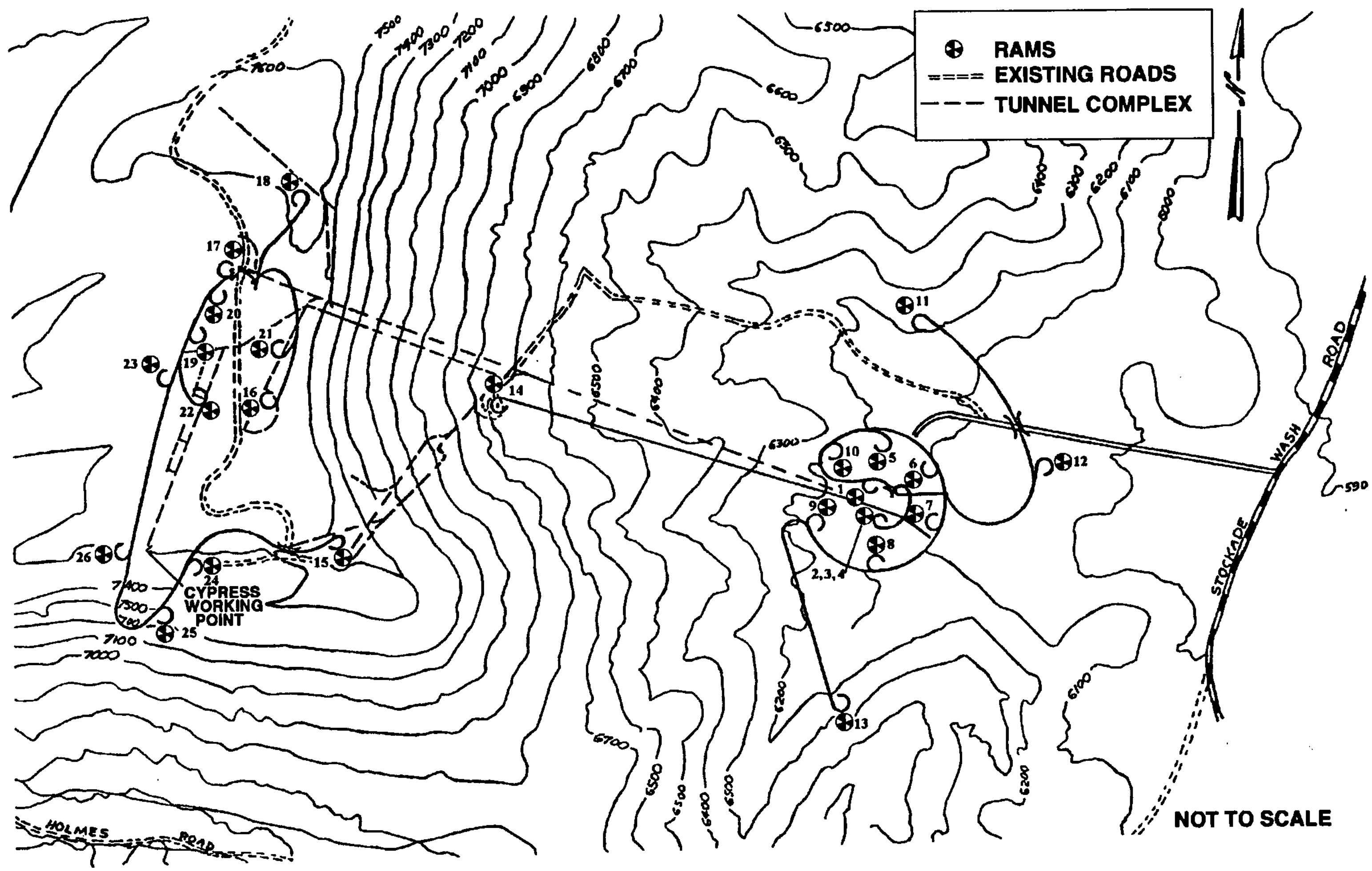

Figure 6-4. CYPRESS event - surface RAMS unit locations.

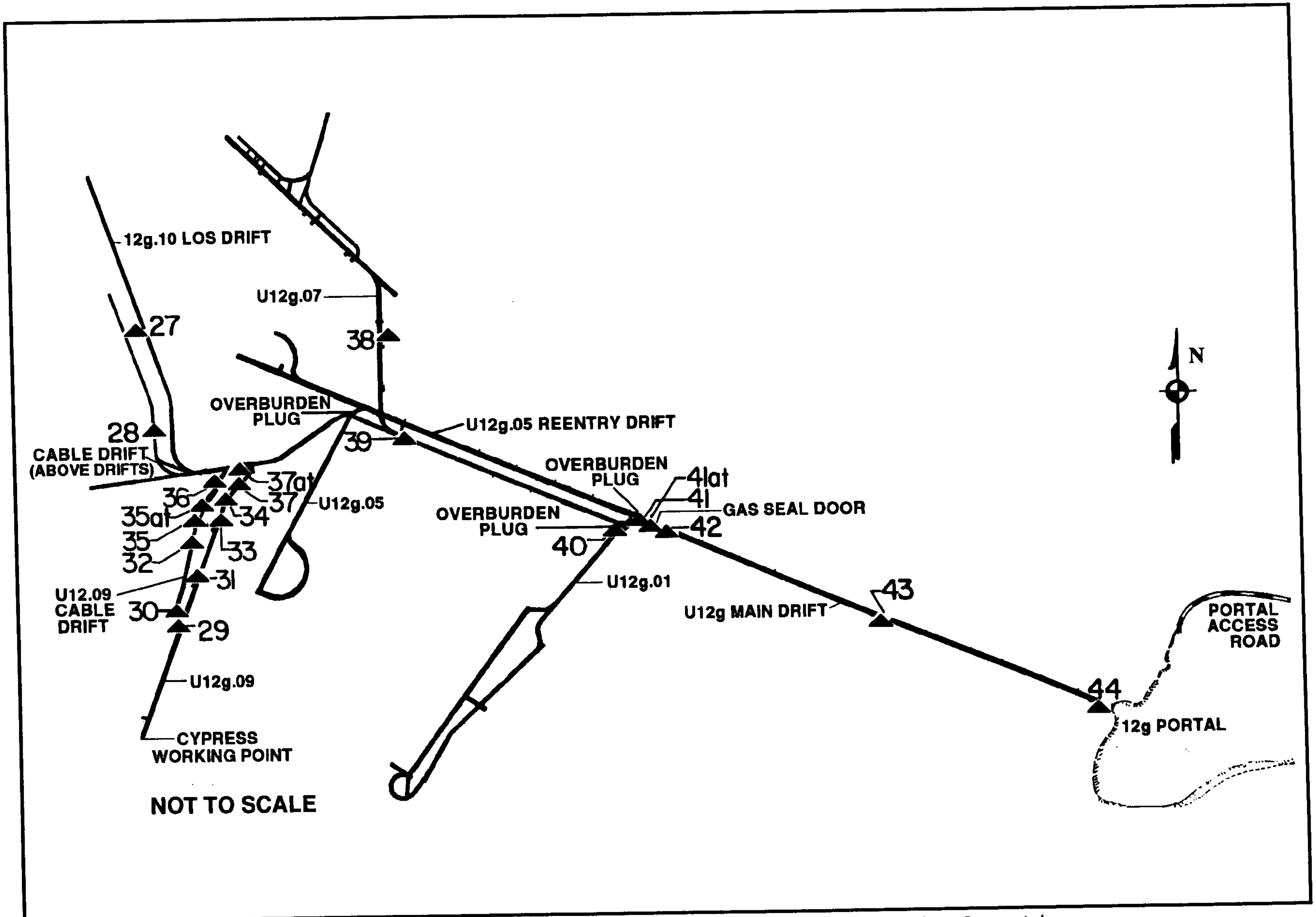

Figure 6-5. CYPRESS event - underground RAMS unit locations.

Final sweep and clearance of the area began at H-12 hours to assure that contractor and agency personnel not associated with this event were out of the closed area. By H-9 hours all personnel, except arming and firing party members, were clear of the closed area.

E. Air Support.

The USPHS had an Air Force U3-A and a Turbo-Beech aircraft on standby at Indian Springs Air Force Base (ISAFB) for cloud tracking and sampling. In Las Vegas, both a USPHS C-45 and an EG&G/NATS aircraft were on standby and available for cloud tracking and sampling missions.

6.3 EVENT-DAY ACTIVITIES.

6.3.1 Preshot Activities.

A readiness briefing was planned for the Test Manager, Advisory Panel, and others in the CP-1 Conference Room at 1430 hours on 11 February. If conditions for the test were favorable, then plans to detonate the device would continue. By 2000 hours all persons except the arming and firing party were to be out of the test area and clear of the muster area. At 0500 hours on 12 February the Test Manager would give the LRL Test Group Director permission to begin final arming of the device, and by 0630 hours all area activity would be completed. The CYPRESS device was detonated at 0818 hours PST on 12 February 1969. Geophones indicated that surface subsidence occurred at approximately 1109 hours on 12 February.

6.3.2 Test Area Monitoring.

Telemetry measurements began at 0819 hours with only five underground RAMS units reading above background levels. All surface RAMS units read background levels. RAMS unit numbers 29-31 and 33-34, located in the U12g.09 drift (No. 30 was located in the cable draft), recorded 28 mR/h to 400 R/h (No. 33) initially. By 1019 hours, the only units reading above background levels were numbers 29, 31, and 33, with readings ranging from 850 mR/h to 9 R/h. Readings decreased rapidly, and when telemetry operations were shut down at 1534 hours on 19 February, only unit No. 33 (0.5 mR/h) read above background levels.

Aerial monitoring conducted by a USAF pilot in a U3-A aircraft left ISAFB at 0755 hours and flew over the portal and SGZ areas at an altitude between 6,800 and 7,800 feet mean sea level. Readings showing background levels were taken beginning at 0827 hours and ending at 0850 hours. No samples were taken, and the mission was terminated at 1104 hours.

6.3.3 Initial Surface Radiation Surveys and Recovery Activities.

An initial survey team (team No. 3) left the Test Director's Barricade at 1025 hours on 12 February to survey the area up to and including the Mesa Trailer Park. By 1245 hours the survey was completed. The maximum reading of 0.03 mR/h was recorded at the filter boxes. This reading is background level for this area. The team left the area by 1150 hours.

Initial survey team No. 1 began surveying the portal area at 1220 hours. Readings were at background levels (i.e., 0.03 mR/h) for the Area 12g portal. At 1230 hours all recovery personnel reported to the portal area to participate in initial recoveries. Remote gas sampling from the WP side of the GSD and from both sides of the OBP in the U12g.09 Cable Drift was initiated at 1300 hours. Samples indicated normal air concentrations inside the tunnel. The tunnel ventilation was turned on at 1415 hours and began pulling air from the entire U12g complex. A remote air sample taken from the ventline at 1422 hours showed a maximum concentration of 18 percent hydrogen. Portal recovery work was completed by 1515 hours. By 1800 hours a base station and associated equipment was operational at the portal.

Surveys by team No. 3 at the mesa vent holes began at 1630 hours. The MADISON, RED HOT, DEEP WELL (never fired), and CYPRESS vent holes were ventilated from the mesa top. Each location was equipped with an air filter and blower. Two air samplers recorded the data. The highest instrument reading, 0.07 mR/h, was recorded at the DEEP WELL vent hole.

6.4 POSTEVENT ACTIVITIES.

6.4.1 Tunnel Reentry Activities.

On 13 February tunnel reentry teams, all dressed in anticontamination clothing and wearing self-contained breathing apparatus, entered the tunnel to conduct surveys and begin recovery operations. Team No. 1 had inspected the U12g Main Drift and opened the GSD by 1100 hours. A survey of the WP side of the GSD showed that the radiation level was 0.05 mR/h. There were no toxic gases, and no positive LEL levels. A visual survey showed no physical damage with a few rocks strewn on the tunnel floor. Work crews proceeded to lay railroad track and establish communications as other crews worked to open the OBP on the WP side of the GSD. By 1320 hours, the reentry team had opened the OBP in the Cable Drift. A survey of this area showed no toxic gases or positive LEL levels. Radiation readings showed background levels. This team then left the tunnel.

Reentry team No. 2 entered the tunnel at 1355 hours to inspect and survey the experiment stations. The team arrived at ES-4 (approximately 1,100 feet from the WP) at 1410 hours noting that tunnel and ground conditions were good and all sand bags were intact and in place at the entrance to the station. A hole through the sand plug was constructed and a survey showed a reading of 100 mR/h. There was adequate air flow, no toxic gases or positive LEL levels, and the radiation level in the ES-4 alcove was 0.15 mR/h. Personnel continued to move on to ES-3, inspect the area, monitor for hazards and then proceed to ES-2 where the radiation reading through the sand plug was 170 mR/h. The face of the ES-2 door read 500 mR/h, and upon opening the door just barely, a reading inside the LOS pipe of 3 R/h was recorded. Again, no toxic gases or positive LEL levels were detected. The team then proceeded back to ES-4 whereupon opening the door to the LOS drift, personnel measured a radiation level of 400 mR/h, 200 ppm of carbon monoxide (CO), and 10 percent of the LEL. This team left the tunnel at 1539 hours.

Reentry team No. 3 entered the tunnel at 1615 hours and proceeded to ES-2Z where the radiation reading was 350 mR/h. Swipes were taken for analysis. The team then monitored the cable hole at ES-2 where 15 ppm CO was measured. The radiation level was 0.15 mR/h by 1730 hours all personnel left the tunnel.

On 14 February, the experiment and equipment disassembly and packaging was started outside the tunnel in the assembly building. Surveying and recovery operations resumed beginning at 0830 hours. The LRL recovery team removed some additional equipment from experiment stations where the radiation level was 120 mR/h at contact. The recovery support team returned to ES-4 at 1100 hours and opened the pin hole camera pipe; the CO concentration was 2,000 ppm. This level dropped quickly to no more than a trace. By 1415 hours that same day, Radsafe monitors had setup self-contained air samplers that were operating at various underground work areas to monitor for airborne contaminants. All results were negative.

Tunnel monitoring continued and some recoveries were made between 17 February and 21 March when all recovery work was completed. DoD experiment survey and recovery took place on 5 March. Swipes of experiment packages from SSS, GRC, LMSC, and KAMAN were taken before any item was removed from the area. Readings were 0.03 to 20 mR/h. These experiments were located in ES-2, ES-3, and ES-4 along with Sandia, LASL, and LRL experiments. The AFWL experiments were surveyed and removed on 10 March. Radiation readings on this equipment ranged between 0.6 and 7.0 mR/h.

6.4.2 Postevent Mining.

Mineback operations began on 14 March to remove LOS pipe components, take core samples, and eventually extend the cable drift and mine a crosscut to ES-1 to recover experiments and equipment. Beginning on 25 March, crosscut No. 1 (mined at 1,095 feet into the extension of the cable drift) was started. This was the first of four crosscuts mined to provide access to the LOS pipe. Some core sampling was done from crosscut No. 4 and at 1,365 feet into the extended cable drift. The maximum intensity of any one core sample, as recorded in the monitor's logbook on 8 July, was 4.5 R/h.

During this period, personnel removed the fast gate assembly and sent it to Albuquerque for further study. Portions of the LOS pipe were also cut out and removed. This work was completed by 26 November. However, indications are that mining activities continued sometime later, because the G tunnel map shows that two additional crosscuts (i.e., a total of six) were eventually mined.

6.4.3 Industrial Safety

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were recorded in the monitors' logbook.

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. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive materials, or any other operation with a potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

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

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials 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 0500 Series for the Nevada Test Site.
3. Individual Safe Operating Procedures (by experimenter organization).
4. CYPRESS 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 LRL Safety Coordinator.

6.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 0819 hours on 12 February when the maximum reading of 400 mR/h was recorded on unit No. 33. Readings decreased rapidly and RAMS units were secured at various times throughout the monitoring period. Only unit No. 33 read above background levels (0.5 mR/h) when all telemetry was shut down at 1534 hours on 19 February.

Initial radiation surveys were conducted at the Mesa Trailer Park, the U12g portal area, and at the mesa vent holes on 12 February between 1025 hours and 1735 hours. No radiation above background levels was detected except at the DEEP WELL vent hole where the reading was 0.07 mR/h.

On 13 February tunnel reentry teams, dressed in anticontamination clothing and wearing self-contained breathing apparatus, were fielded to visually inspect and survey the tunnel and the experiment stations as well as to recover experiments and equipment. The maximum radiation level recorded during these activities was 3 R/h inside the LOS pipe at ES-2, while 10 percent of the LEL was measured at ES-4 later that day. The maximum concentration of toxic gas was 2,000 ppm CO when the pin hole camera pipe was opened at ES-4 on 14 February. Recoveries were completed by 21 March. Mineback operations began on 14 March.

Mineback operations began on 14 March. Four crosscuts were mined from the Cable Drift that was eventually extended to a position opposite ES-1. These crosscut drifts facilitated the removal of LOS pipe components, core sampling in areas near experiment stations, and recovering experiments from ES-1. The maximum reading recorded on a core sample was 4.5 R/h. By 26 November 1969 core sampling was accomplished and portions of the LOS pipe and the Fast Gate Assembly were removed. Additional mining activities were accomplished sometime later.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to the CYPRESS radex areas over a non-continuous time frame from 12 February to 28 July 1969. Minimum detectable gamma exposure with the NTS film dosimeter was 30 mR. Area Access Register data are summarized below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	1,516	500	3
DoD Participants	41	10	0

SECTION 7

CAMPHOR EVENT

7.1 EVENT SUMMARY.

The CAMPHOR event was a Sandia Laboratories (SL)-sponsored weapons-effects test, conducted at 1130 hours PDT on 29 June 1971, with a yield of less than 20 kilotons. The device, provided by Lawrence Radiation Laboratory (LRL), was detonated in the U12g.10 drift of G tunnel complex (Figure 7-1) emplaced approximately 6,650 feet from the tunnel portal at a vertical depth of burial at the working point (WP) of 1,390 feet. The purpose of the event was to determine the response of materials and hardware to a nuclear environment. To support this objective, experiments were fielded in the categories of current and advanced systems, advanced technology development, phenomenology, instrumentation development, and diagnostics. The DoD participation included four DNA-managed projects that fielded experiments in the categories of advanced systems, technology development, and phenomenology.

There were two radioactive effluent releases that occurred from this event. At H+60 minutes, seepage occurred from the cable rise building on the mesa lasting for approximately 30 minutes. Seepage from the portal began at H+3 hours, 52 minutes and lasted for approximately 4.3 days. In addition to these releases, a controlled, filtered ventilation (accomplished with the permission of the Test Manager) of the tunnel complex inside the gas seal door (GSD) was started at 1034 hours on 27 July. Radioactive gases, primarily xenon-133, were released over a three-day period. No radioactive releases were detected offsite from this event.

7.2 PREEVENT ACTIVITIES.

7.2.1 Responsibilities.

Safe conduct of all CAMPHOR project activities in Area 12 was the responsibility of the Sandia Test Group Director. Responsibilities of the AEC and its contractor personnel were in accordance with established AEC-DoD agreements or were the subject of separate action between Field Command/DNA and the AEC Nevada Op-

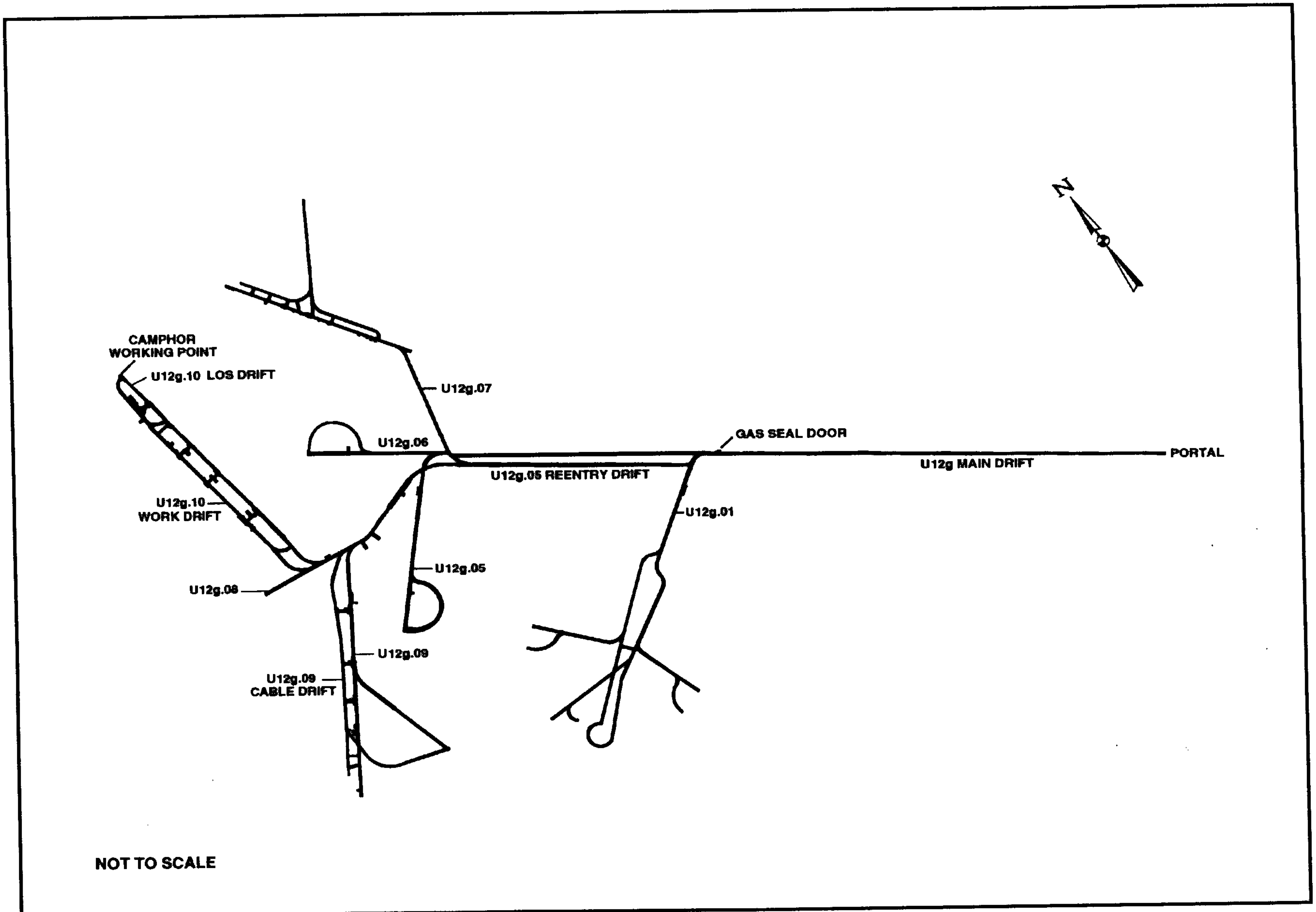

Figure 7-1. CAMPHOR event - tunnel layout.

erations Office. The AEC Test Manager was responsible for safety of onsite personnel and the public during the test.

Project agencies were responsible for designing, preparing, and installing experiments or delivering them to the installation contractor. After the event, each of these agencies was responsible for removing samples, analyzing instrument and sample data, and preparing project reports on their respective experimental results. Specifically, the DNA Test Group Director was responsible for coordinating the DoD experiments with the Sandia Test Group Director and informing the AEC Test Manager of the status of the DoD program.

Because LRL fielded the device, the LRL Test Group Director was responsible to the AEC Test Manager for radiological safety within a 6,000-foot radius of surface ground zero (SGZ). This responsibility was in effect from the time the device was moved to the zero site until device detonation. After device detonation, the AEC Test Manager relieved the LRL Test Group Director of this responsibility according to the provisions of the NTSO SOP 0524 and issued the responsibility to the Sandia Test Group Director. Device safety and security procedures in the GZ area, in the Timing and Firing Control Room, and at the cable plant were accomplished according to the provisions of the AEC Manual, Chapter 0560 and the individual NVOO Nuclear Safety Study.

REECo Radiological Safety Department (Radsafe) provided onsite radiological safety support services and was responsible to the Sandia Test Group Director while the testing area was under his control. When the testing area was under the control of the AEC Test Manager, REECo Radsafe provided monitoring support, area control, and surveillance.

Firing circuits and timing signals were provided by EG&G. The responsibility for stemming the device was assigned to Sandia, and LRL, while LRL was responsible for device emplacement and arming.

7.2.2 Planning and Preparations.

A. <u>Area Facilities Preparation and Construction</u>.

The CAMPHOR event, located in the U12g.10 drift at the southern end of Rainier Mesa, was physically arranged so that the downhole cable plant and Mesa Trailer Park could serve other events in addition to CAMPHOR. This same mesa facility along with the portal area facilities were previously used for the CYPRESS event. Figure 7-2 shows the CAMPHOR tunnel layout positioned relative to the mesa facilities.

The basic design of CAMPHOR event was based on experience gained from previous underground tests, particularly GUM DROP, MIDI MIST, and CYPRESS and was very similar to CYPRESS. Containment depended on closing and sealing the line-of-sight (LOS) pipe by utilizing ground shock generated by the nuclear detonation. The backup containment system was deployed at approximately 390 feet, just inside experiment station 2Z (ES-2Z). This system consisted of a concrete plug to seal the tunnel and an explosive gas-driven steel door (i.e., a gas seal valve) that sealed the LOS pipe. The gas seal valve was surrounded by a concrete plug constructed of expanding concrete to overcome shrinkage and provide a positive contact with all interfaces. These features were designed to contain peak pressure of 1,000 psi and temperatures of 1,000°F. Additionally, the overburden plugs (OBPs) in both the LOS and Work drifts and the gas seal door (GSD) in the main U12g tunnel drift provided another barrier to help prevent an event release should these other systems fail. Experiment protection from high-velocity debris was provided by a high explosively driven crumpled section of the LOS pipe (i.e., dimples) between 105 and 140 feet; two pneumatically driven fast gates at approximately 372 and 380 feet; and two debris protection doors at approximately 530 and 760 feet. All cables and cable bundles were gas blocked to reduce the probability of release of radioactivity via these routes.

The LOS configuration was also similar to the CYPRESS event. The CAMPHOR LOS pipe had experiment stations located at approximately 195, 408, 550, 778 and 1,100 feet from the WP. This pipe diverged from four inches to a maximum diameter of 92 inches at 1,100 feet (ES-4). Instrumentation cables were routed through the various stations and through the crosscuts to the work drift and then through the vertical cable holes to the Mesa Trailer

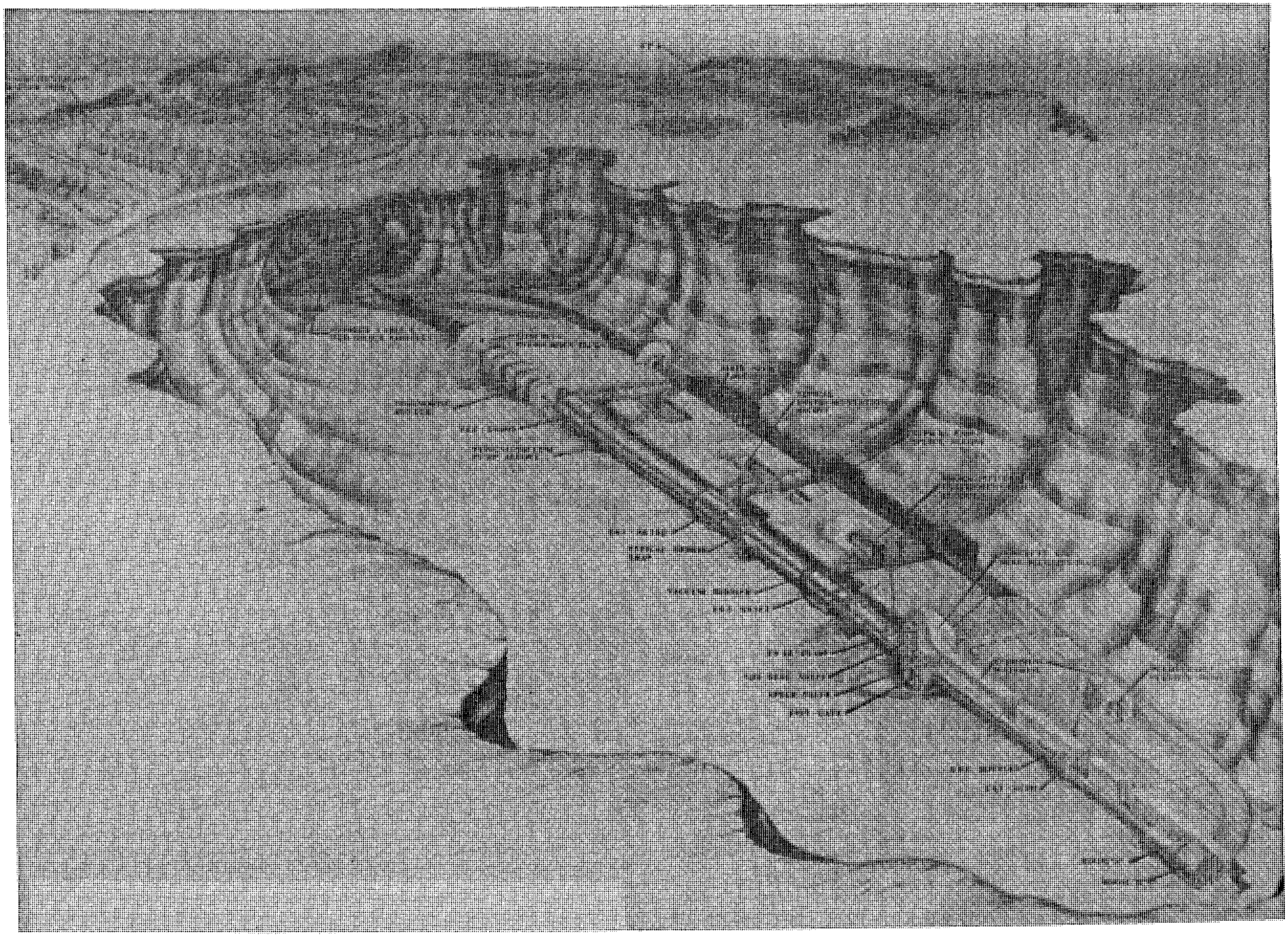

Figure 7-2. CAMPHOR event - cutaway of tunnel layout relative to mesa facilities.

Park. The LOS and Work drifts layout is shown in Figure 7-3.

Stemming design was based on experience gained from GUM DROP and CYPRESS events. The Work drift was stemmed out to a distance opposite 425 feet in the LOS drift. The first 260 feet was stemmed with rock-matching grout (RMG); the portion from 260 to 325 feet was stemmed with a low-strength grout (LSG); and a modified RMG was used from 325 to 425 feet. The LSG was used to ensure good ground shock compaction in the area where cable blocks were installed.

The LOS stemming design included four voids, one more than CYPRESS, and similar to that used in GUM DROP. These voids (located at 60 to 75 feet, 105 to 121 feet, 160 to 188 feet, and 280 feet) were designed to interrupt any leak path provided by the pipe or cables. The first 60 feet of the drift was stemmed with RMG. From 75 to 105 feet a LSG was used to get a more effective closure of the LOS pipe. A modified RMG was used from 121 to 160 feet to again initiate LOS pipe closure as soon as possible. From 188 to 260 feet and 280 to 364 feet a LSG was used because this material compacts well under ground shock loading. Figure 7-4 shows the stemming design.

CAMPHOR tunnel construction began in July 1967 and was completed by July 1968. Plans for LOS pipe installation were to begin in September 1970 and be completed by November 1970. Experiment installation was scheduled to begin in December 1970, with the first dry runs taking place in January 1971.

The experiment stations contained both DoD- and AEC-sponsored experiments. Sandia Laboratories conducted both effects and diagnostics studies for the AEC. These tests used nearly 73 percent of the allotted exposure area. The DoD agency experimenters, LRL, and Los Alamos Scientific Laboratory (LASL) used a combined 27 percent of the exposure area. The DoD experiments were located in all stations except ES-1.

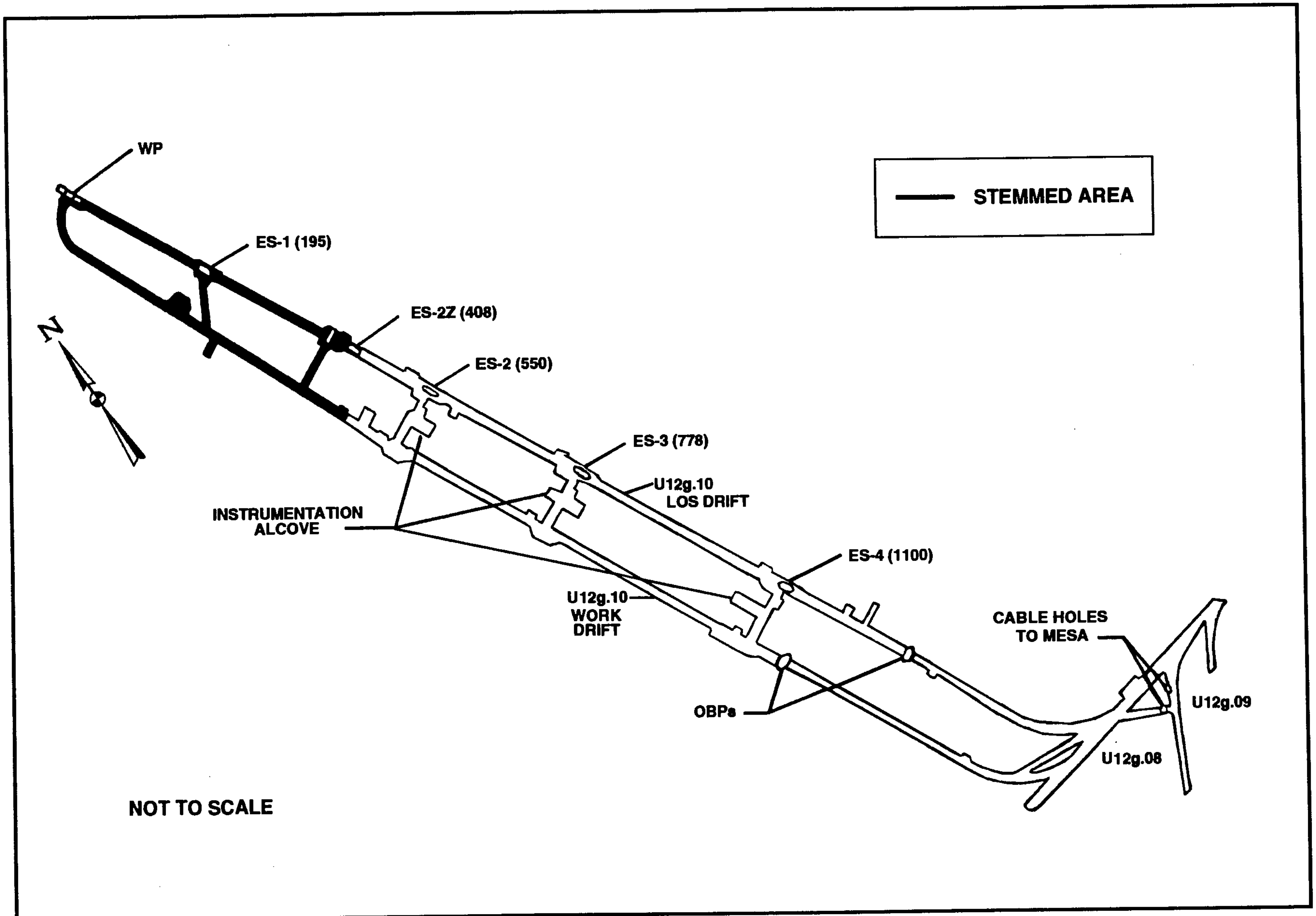

Figure 7-3. CAMPHOR event - work and LOS drifts layout.

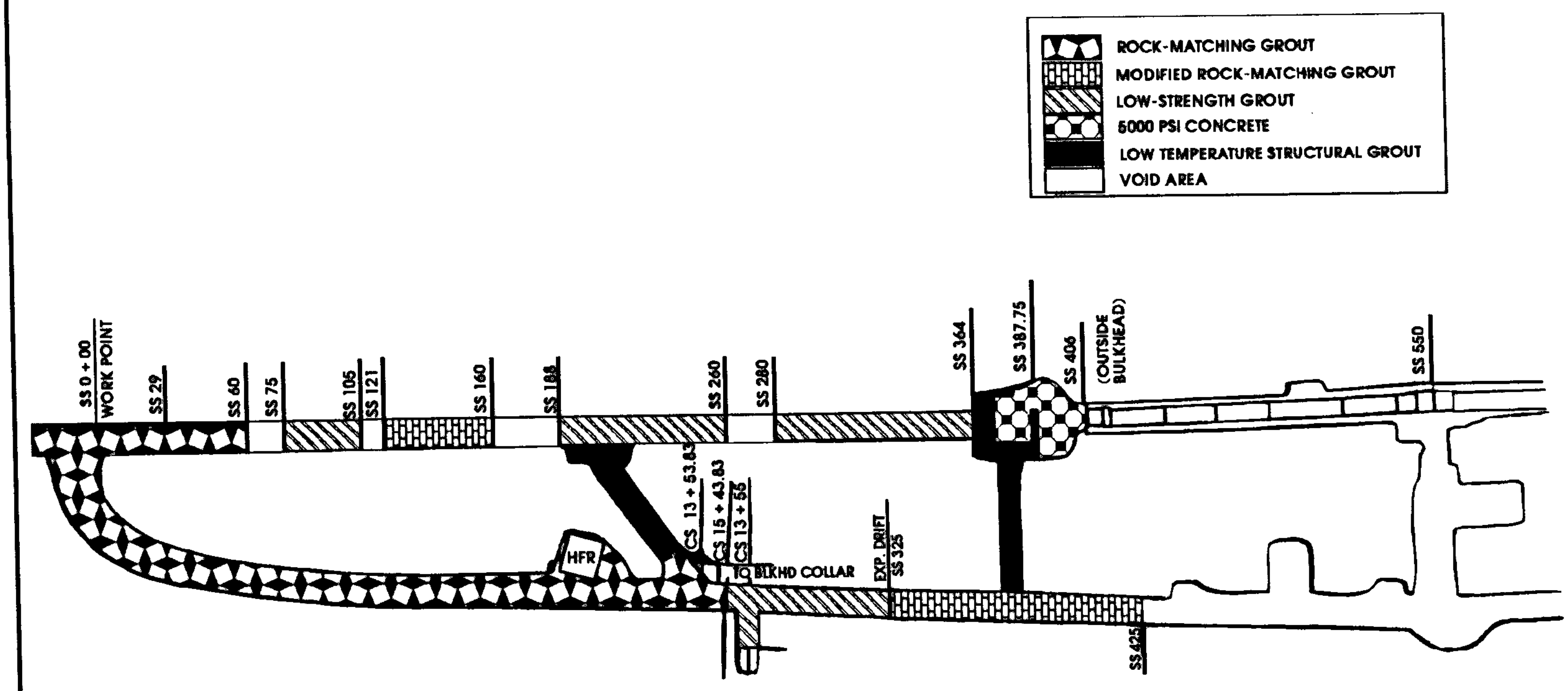

Figure 7-4. CAMPHOR event - stemming design.

The DoD-sponsored experiments, coordinated through DNA, were conducted by the following agencies or contractors: Air Force Weapons Laboratory (AFWL), performed six experiments, two of which were sponsored by the Space & Missile Systems Organization (SAMSO), involving upgrade silo, advanced materials, and phenomenology studies; Kaman Sciences Corporation (KSC) conducted lethality phenomenology and radial stress studies; Lockheed Missiles & Space Company (LMSC) conducted structural damage studies; and Effects Technology, Incorporated (ETI) conducted PREDIX studies.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were in accordance with AEC Manual Chapter 0524 and requirements of the responsible Sandia Test Group Director or his representative. Radsafe provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimetry packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during dry runs. Party monitors were briefed regarding reentry, sample recovery, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in area reentry parties as needed. Radsafe personnel also were standing by at the Test Director's Barricade prior to detonation to perform surveys and provide emergency support as directed. Routine support included issuing anti-contamination equipment and material, portable instruments, and dosimeters; operating area control check stations; and performing 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.

In addition to the permanent RAMS units, 50 temporary units provided surface and underground coverage for CAMPHOR. Also, four air sampling trailers were used to sample at the ventlines, and one air sampler was placed at the portal. Table 7-1 and Table 7-2 list the locations of both surface and underground RAMS respectively. Figure 7-5 and Figure 7-6 show the locations of the surface and underground RAMS respectively. All RAMS were installed a minimum of five days prior to scheduled device detonation. Telemetry readout was recorded manually at CP-2 and reported via telephone to CP-1.

The Western Environmental Research Laboratory (WERL) operated by the Environmental Protection Agency (EPA) (formerly the Southwest Radiological Health Laboratory [SWRHL], operated by the U.S. Public Health Service [USPHS]) was responsible for providing offsite surveillance. The EPA operated 100 air sampling stations and 30 gamma-rate recorder stations in offsite locations. Twenty-nine EPA personnel were fielded for these surveillance activities.

D. Security Coverage.

Beginning at 2000 hours on 28 June 1971, muster and control stations for the area were established. 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 the use of roadblocks, access authorizations, and a Schedule of Events. Parties could enter the area only with the permission of the Test Group Director or Test Manager. Nonessential traffic was diverted around the controlled area.

Table 7-1. CAMPHOR event RAMS unit locations 29 June 1971.

SURFACE

STATION	LOCATION
From the U12g Portal unless otherwise indicated:	
1	At the Portal
2	156 feet S 3° W azimuth on the filter system
3	156 feet S 3° W azimuth on the filter system
4	156 feet S 3° W azimuth on the filter system
5	280 feet N 31° E azimuth
6	521 feet N 60° E azimuth
7	430 feet S 78° E azimuth
8	429 feet S 20° E azimuth
9	144 feet S 43° W azimuth
10	261 feet N 18° E azimuth
11	1,367 feet N 18° E azimuth
12	1,448 feet N 82° E azimuth
13	1,207 feet S 16° W azimuth
14	1,061 feet S 73° W azimuth
15	479 feet at the drain line
From Cable Hole Number 2 unless otherwise indicated:	
16	120 feet on the ventline
17	At DEEP WELL SGZ
18	At RED HOT SGZ
19	At DOOR MIST Cable Hole #1
20	At Cable Hole #2
21	272 feet N 49° E azimuth
22	309 feet S 65° E azimuth
23	222 feet S 33° W azimuth
24	278 feet N 58° W azimuth
From SGZ:	
25	315 feet S 07° E azimuth
26	425 feet N 65° W azimuth
27	307 feet N 34° E azimuth

Table 7-2. CAMPHOR event RAMS unit locations 29 June 1971.

UNDERGROUND

STATION[14]	LOCATION
30	1,055 feet into the U12g.10 LOS drift
31	830 feet into the U12g.10 LOS drift
32	510 feet into the U12g.10 LOS drift
33	400 feet into the U12g.10 LOS drift
34	300 feet into the U12g.10 LOS drift
35	1,130 feet into the U12g.10 work drift
36	840 feet into the U12g.10 work drift
37	485 feet into the U12g.10 work drift
37 AT[15]	485 feet into the U12g.10 work drift
38	400 feet into the U12g.10 work drift
38 AT[15]	400 feet into the U12g.10 work drift
39	750 feet into the U12g.08 drift
40	300 feet into the U12g.09 cable drift
41	275 feet into the U12g.09 LOS drift
42	230 feet into the U12g.07 drift
43	1,300 feet into the U12g.05 reentry drift
From the U12g Portal unless otherwise indicated:	
44	2,500 feet into the U12g main drift
44 AT[15]	2,495 feet into the U12g main drift
45	2,375 feet into the U12g main drift
46	1,200 feet into the U12g main drift
47	50 feet into the U12g main drift
48	620 feet into the U12e.11 drift
49	3,550 feet into the U12e main drift

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14 Station numbers 28 and 29 were not used.
15 Probe buried in tunnel invert (floor) or sidewall.

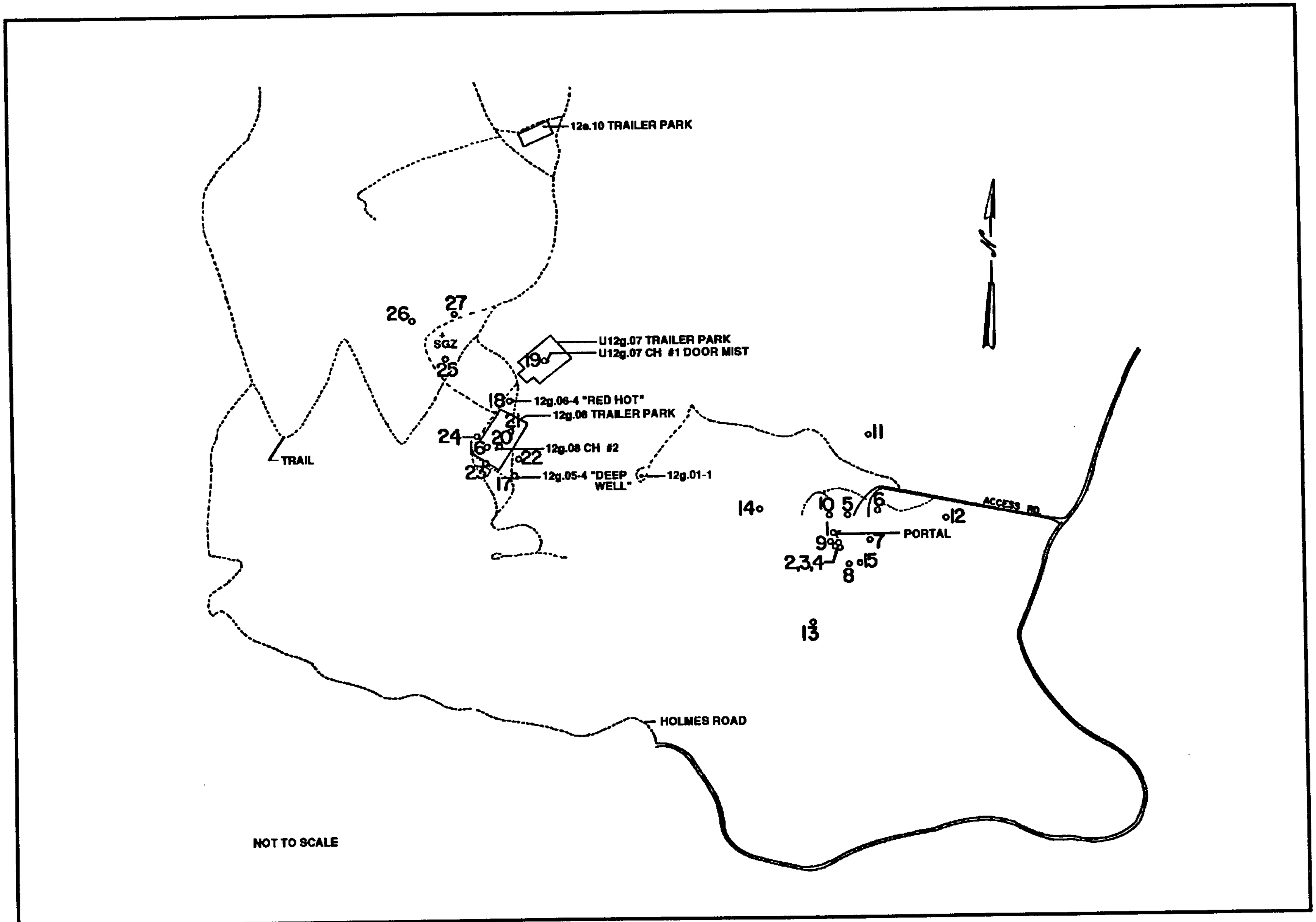


Figure 7-5. CAMPHOR event - surface RAMS unit locations.

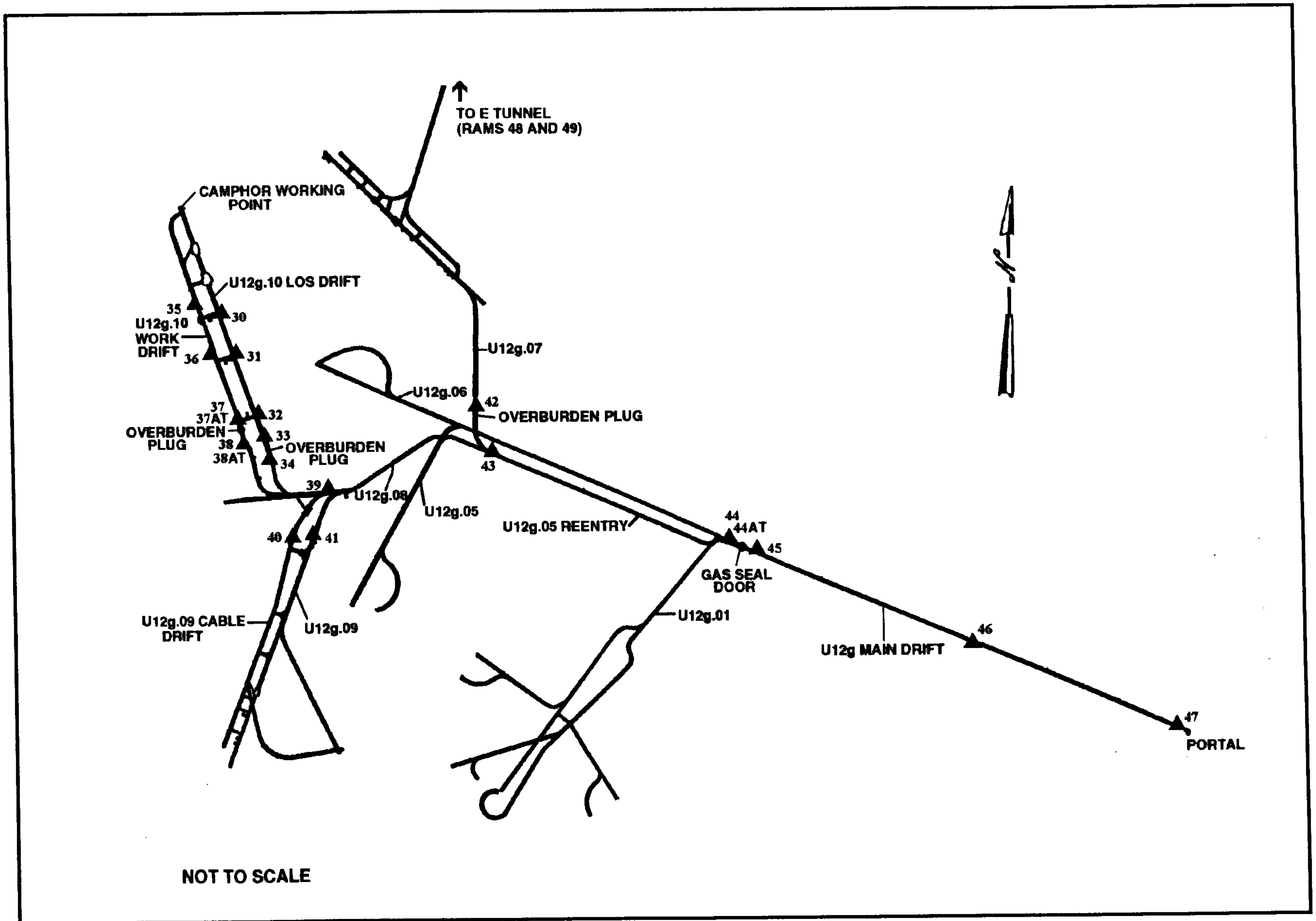


Figure 7-6. CAMPHOR event - underground RAMS unit locations.

Final sweep and clearance of the area began at 2235 hours on 28 June to assure that contractor and agency personnel not associated with this event were out of the closed area. By 0400 hours on 29 June all personnel, except arming and firing party members, were clear of the closed area.

E. Air Support.

The EPA had an Air Force U3-B and a modified C-45 with turbo-prop engines (i.e., a Vegas 8) on standby at Indian Springs Air Force Base (ISAFB) for cloud tracking and sampling. In Las Vegas, both an EPA Turbo-Beech and an EG&G/NATS Turbo-Beech were on standby and available for cloud tracking and sampling missions.

7.3 EVENT-DAY ACTIVITIES.

7.3.1 Preshot Activities.

A readiness briefing was first held for the Test Manager, Advisory Panel, and others in the CP-1 Conference Room at 1430 hours on 28 June. The weather forecast for 0800 hours on 29 June was not favorable, and a decision was made to continue and hope for a change in the wind direction. Weather conditions improved and at a 1000 hours readiness briefing on 29 June, plans were made to detonate the device at 1100 hours. All persons except the arming and firing party were to be out of the test area and clear of the muster area by approximately 0400 hours. At 0755 hours the Test Manager gave the LRL Test Group Director permission to begin final arming of the device, and by 1000 hours all area activity was completed. After a short technical delay, the CAMPHOR device was detonated at 1130 hours PDT on 29 June 1971. Within 10 seconds after detonation increased pressure, temperature, and radiation levels in both the LOS and work drifts were noted. Monitoring signals were lost at about 20 to 30 seconds. Indications were that a stemming failure occurred.

7.3.2 Test Area Monitoring.

Telemetry measurements began at 1131 hours on 29 June with underground RAMS unit numbers 30 through 43 reading greater than 1,000 R/h. By 1132 hours these units were inoperative. RAMS unit numbers 44, 44 AT, and 45 were all reading greater than 1,000 R/h by 1139 hours, with unit 44 reading remaining at 1,000 R/h until 1815 hours when the reading began to drop.

By 1143 hours RAMS unit No. 20, located on the mesa at Cable Hole No. 2, initially indicated 80 mR/h. That reading increased to 250 mR/h by 1146 hours at which time unit numbers 16, 22, 23, and 24 indicated readings of 1-8 mR/h. By 1300 hours these units (except No. 20) were reading background radiation levels. References to when RAMS units were actually shut down are not available.

Aerial monitoring was conducted on 29 June by two WERL monitors and a USAF pilot in a U3-B aircraft between 1143 and 1235 hours at an altitude between 7,800 and 8,000 feet mean sea level. Several passes were made over SGZ and the Mesa Trailer Park areas. The maximum reading was 0.12 mR/h, recorded at 1202 hours. A Vegas 8 aircraft conducted aerial sampling from 1145 until 1232 hours and again from 1445 to 1522 hours. The maximum activity recorded on a particulate sample was 400 pCi/m^3, sampled over the Mesa Trailer Park at 1232 hours.

7.3.3 Initial Surface Radiation Surveys and Recovery Activities.

By 1355 hours Radsafe monitors and security personnel had moved area barricades to the intersection of Orange and Rainier Mesa Roads and had opened all areas to traffic except Area 12. Initial survey teams numbers 1 and 4 had moved to the portal area accompanying electricians who shut off the power to the cables. This was accomplished by 1600 hours. Shortly afterward team No. 4 proceeded to the Mesa Trailer Park. Initial survey team No. 2 accompanied Sandia recovery party personnel to the portal area at 1612 hours where radiation levels were measured at 1 mR/h. As a precaution, all personnel in the portal area donned full-face respirators. By 1700 hours survey teams Nos. 3 and 4 had completed a survey of the Mesa Trailer Park where a reading of 12 mR/h at the cable shack was recorded. All other areas of the trailer park were reading background radiation levels.

By 1910 hours all personnel had returned to the check point in Area 2. For security reasons the check point was moved to the Area 2 construction yard at 2245 hours.

7.4 POSTEVENT ACTIVITIES.

7.4.1 Tunnel Reentry Activities.

Between 30 June and 26 July sampling and recoveries in the portal area continued as preparations were made to ventilate the tunnel complex. This work was being done so that an exploratory reentry into the tunnel beyond the GSD would be possible. A controlled ventilation of the tunnel complex was started at 1034 hours on 27 July. Continuous monitoring showed radiation levels approximately 2 to 3 mR/h (beta plus gamma) with the maximum reading of 60 mR/h on the filter boxes. Sampling at the downhole cable area was also conducted while tunnel ventilation was ongoing. The maximum reading on a gas sample was 7 mR/h (beta plus gamma).

On 28 July reentry personnel, dressed in anticontamination clothing, entered the tunnel and arrived at the GSD at 1408 hours. The radiation level near contact with the door was 20 mR/h. There were no toxic gases or positive LEL levels, and the oxygen level was a normal 21 percent. Upon proceeding inside the GSD, personnel found extensive damage to the ventline opposite the RED HOT (U12g.06) and reentry drifts. The ventline was almost collapsed opposite the MADISON drift (U12g.01). Radiation readings were as high as 1 R/h at 40 feet beyond the tunnel curve into the U12g.08 drift, and the carbon monoxide concentration was 10 ppm. Personnel left the tunnel at 1451 hours. The next day the reentry team proceeded into the tunnel as far as the 3,225 foot station. The maximum reading was 12 R/h at near contact with the left rib. A decision was made to terminate work, and personnel were out of the tunnel by 1313 hours.

During the next two months Sandia personnel considered several approaches for a reentry program. It was decided that the elevated radiation levels inside the GSD precluded the use of the existing drift for reentry work. On 26 August personnel, dressed in anticontamination clothing, began to make a damage assessment of the tunnel for cleanup and rehabilitation purposes. Cleanup started on 7 September that included decontamination of the main U12g tunnel from the GSD to the U12g.01 drift plug (approximately 300 feet). Decontamination consisted of washing down tunnel walls and spraying sealant on the walls to keep contamination levels as low as possible. As the contamination was fixed, four to six inches of the invert were removed and replaced with clean ballast to further reduce the exposure rate.

Additional sandbags were placed at the opening of the U12g.06 drift, and a new sandbag bulkhead was constructed at the turnout for the reentry drift (U12g.08). This was accomplished so that the mining of a new reentry bypass tunnel could be started at about 200 feet from the GSD off the U12g.01 drift.

7.4.2 Postevent Mining.

Mineback operations began on 5 October off the right rib of the U12g.01 drift (Figure 7-7). As the reentry mining progressed, personnel continued decontamination work in the region between the GSD and the U12g.01 drift in an attempt to lower exposure rates and contamination levels in the area. On 17 December 1971 miners, dressed in anticontamination clothing and full-face masks, broke through into the U12g.05 drift. A reentry team was staged from the opening, walking toward the Deep Well Cavity. About 150 feet into the U12g.05 drift, ground support conditions caused the team chief to abort the reentry, and the team returned to the U12g.01/.05 intersection. A maximum radiation reading of 1 R/h was recorded during this entry. Loose contamination at the intersection was fixed in place with sealant. Sandbag bulkheads were placed on both sides of the U12g.05 reentry drift to preclude personnel access and lower exposure rates and contamination levels.

Mining operations continued in the reentry heading and on 3 January 1972 miners broke through into the U12g.08 drift. Mining personnel examined this drift and determined that it was structurally safe to attempt an entry to the LOS and bypass drift overburden plugs. The radiation field in the vicinity of the crossing (U12g.05/.08) was 15 mR/h but increased to 200-400 mR/h down the drift toward the portal. No toxic gas or positive LEL levels were detected. The oxygen level was 20 percent, and the carbon dioxide concentration was 5,000 ppm.

A six-member reentry team was assembled to reenter to the U12g.10 LOS and bypass drift OBPs. This team was suited out in full anticontamination clothing, and personnel were wearing Draeger self-contained breathing apparatus (SCBA). A rescue team was standing by at the fresh air station. This first entry had to be aborted because of low oxygen on one team member's SCBA. After conferring with team members, a decision was made to reduce the team size to four, replace the oxygen bottles on the breathing apparatus of the remaining team members, and make another attempt to complete the reentry. The team was success-

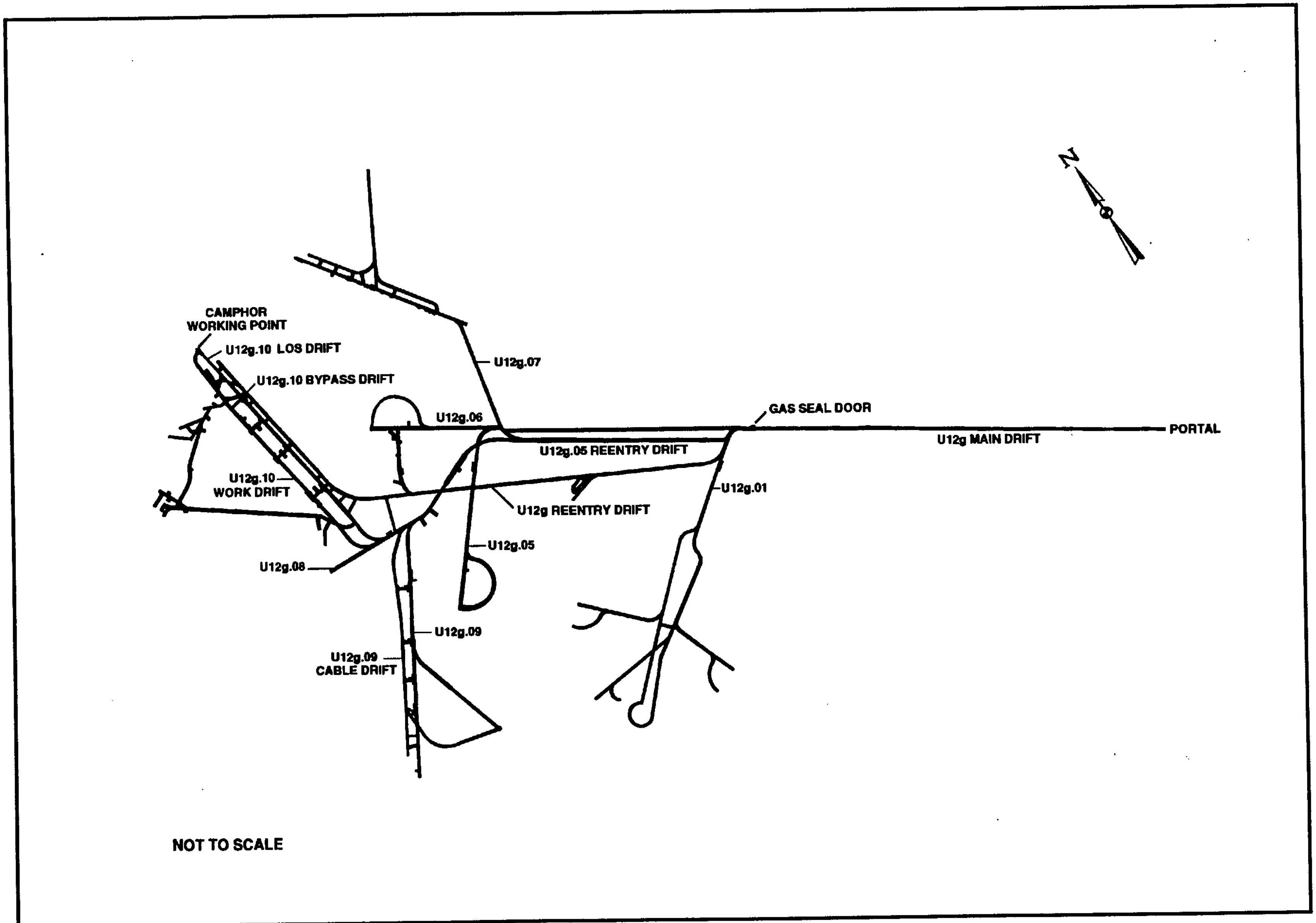


Figure 7-7. CAMPHOR event - modified postevent tunnel layout.

ful on this second attempt, finding the OBP in the U12g.10 LOS drift intact with little or no damage in this area. A hole (approximately four feet by eight feet) was eroded through the OBP in the bypass drift where cables had penetrated the plug. Radiation levels on this entry ranged from 200 to 700 mR/h, and a maximum of 10 ppm carbon monoxide was detected. After completing this reentry work, a sandbag plug was constructed in the U12g.08 drift to close off access toward the U12g.10 part of the tunnel complex and to reduce contamination potential of the tunnel.

Mining continued on a parallel drift along the east side of the U12g.10 LOS drift from the vicinity of ES-4 to the vicinity of ES-1. Miners wore anticontamination clothing during this entire postevent mining. By 7 February miners drilled probe holes from the reentry drift into ES-4. A radiation probe survey into the drill hole indicated radiation levels were as high as 400 mR/h. Miners completed a crosscut to ES-4 in March. The reentry team found the LOS pipe had buckled in front of ES-4; the rear end of ES-4 was substantially damaged; and the whole station was pushed away from the WP about 40 feet. Experiment recovery in ES-4 was accomplished between 13 and 28 March through a new crosscut and alcove (ES-4A) mined for sample recovery. Recovery personnel wore anticontamination clothing and full-face respirators during recovery activities. After several days of experiment recovery, it was decided that double anticontamination clothing was necessary. Because of gross contamination conditions during sample recovery with readings as high as 2.0 R/h, decreased work periods and more frequent personnel monitoring schedules were instituted.

The miners completed the entire reentry drift in April. Observations made by reentry personnel, when entering the LOS drift at ES-2Z, ES-2, and ES-3 locations, indicated that all three of these stations were stacked up in front of ES-4 in one big debris and muck pile. This pile also contained train tracks, sample recovery canister bottles, parts of the gas seal valve and fast gates, and large quantities of stemming material. Much of the debris pile was unidentifiable, but some experiments were recovered intact. Because working in the debris pile was extremely hazardous and expensive, and because of the condition of the recovered material, this work was discontinued.

Miners continued to mine crosscuts to the LOS drift and to mine an access drift across the LOS drift to the high fluence recoverable station (HFR) that was uncovered in May. Grout from around the HFR had flowed into the interior of the station, essentially cementing experiments and instrumentation in place. No experiments or instrumentation were recoverable from this location. Drilling, coring, and cleanup work continued through November 1972. Coring operations required miners to wear full-face masks, with Type N canisters, because carbon monoxide concentrations were as high as 1,000 ppm. Decontamination and cleanup work at various crosscut and reentry drift locations kept radiation levels typically below 500 mR/h during coring operations.

In November 1972 because of limited funding, full-time G Tunnel operations were discontinued. Cleanup and decontamination work was completed. The tunnel entrance was secured, and appropriate barricades and radiation warning signs were posted by 5 December 1972.

7.4.3 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were recorded in the monitors' logbook.

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. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive material, or any other operation with a potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

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

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials 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 0500 Series for the Nevada Test Site.
3. Individual Safe Operating Procedures (by experimenter organization).
4. CAMPHOR 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 LRL Safety Coordinator.

7.5 RESULTS AND CONCLUSIONS

Telemetry measurements began at 1131 hours on 29 June with readings greater than 1,000 R/h recorded on underground RAMS unit numbers 30 through 45 within ten seconds of the detonation. Most of the units were rendered inoperative almost immediately with unit 44 remaining at 1,000 R/h until 1815 hours. The maximum reading recorded above ground was 250 mR/h at unit No. 20 at Cable Hole No. 2 on the mesa.

Initial radiation surveys were conducted at both the portal and the Mesa Trailer Park areas between 1355 and 1910 hours on 29 June. Initial survey teams and Sandia recovery personnel worked at the portal area where the radiation level was 1 mR/h. A survey at the Mesa Trailer Park showed a maximum reading of 12 mR/h at the cable shack.

Because of high radiation levels, a controlled ventilation of the tunnel complex was accomplished before reentry personnel were able to work beyond the GSD. This work began on 28 July when reentry personnel, dressed in anticontamination clothing, proceeded as far as 40 feet beyond the curve into the U12g.08 drift, where a radiation level of 1 R/h was recorded. The team assessed the damage and surveyed for toxic gas levels. The maximum carbon monoxide concentration was 10 ppm.

After a two-month period when personnel studied the options for reentry and recovery operations, tunnel cleanup began on 7 September. Personnel wore anticontamination clothing during all of these operations and used full-face masks or self-contained breathing apparatus most of the time. Work began on 5 October to mine a new reentry drift from just beyond the GSD off the U12g.01 drift to just east and parallel to the U12g.10 LOS drift beyond ES-1. Mineback, decontamination and tunnel rehabilitation, experiment recovery, and core sampling continued until November 1972. Experiments from ES-4 were recovered; most of the remaining experiments and equipment were stacked up in a debris and muck pile in front of ES-4. Because of the gross contamination conditions, (i.e., radiation readings as high as 2.0 R/h) that existed during this period, personnel work shifts in the tunnel were decreased and more frequent personnel monitoring was conducted.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to CAMPHOR radex areas over a non-continuous time frame between 29 June 1971 and 9 January 1973. Minimum detectable gamma exposure with the NTS film dosimeter was 30 mR. Area Access Register data are summarized below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	9,288	1,545	16
DoD Participants	118	600	13

SECTION 8

REFERENCES

References are not indicated within the text of this report. However, key references are included in this list by section or part. Most unclassified references are available at the DOE/NV Public Reading Facility. Security-classified references are available only to persons with appropriate security clearances and a need-to-know justification for this information. They may be obtained through the Defense Special Weapons Agency/HQ (DSWA/HQ) Technical Resource Center in Alexandria, Virginia.

The Public Reading Facility is operated by Bechtel Nevada, the custodian of DoD and DOE nuclear testing personnel dosimetry records and other reference documents on DoD participation in atmospheric, oceanic, and underground nuclear weapons events. Arrangements may be made to review available references for this report at the Public Reading Facility by contacting one of the following:

Safety and Health Division
U.S. Department of Energy
Nevada Operations Office
Post Office Box 98515
Las Vegas, NV 89193-8515
(702)295-0961

or

DOE/NV Public Reading Facility
Bechtel Nevada
Post Office Box 98521 M/S NLV040
Las Vegas, NV 89193-8521
(702) 295-1628
e-mail: cic@nv.doe.gov

Major source documents can also be purchased through the National Technical Information Service (NTIS) listed below:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650
(Sales Office)

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

- *   Available through the NTIS and the DOE/NV Public Reading Facility.
- ** Health Physics Department historical files, contact the DOE/NV Public Reading Facility; some information may be subject to Privacy Act restrictions.
- *** Available through the DSWA/HQ Technical Resource Center, and subject to security clearance requirements.

PREFACE

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

2. U.S. Senate Committee on Veterans Affairs, Veterans Claims for Disabilities from Nuclear Weapons Testing, U.S. Government Printing Office, Washington, DC, 1979. (UNCLASSIFIED)

3. Harris, P.S., et al., Defense Nuclear Agency, Operation Plumbbob, DNA 6005F, 15 September 1981.* (UNCLASSIFIED)

4. Office of External Affairs, U.S. Department of Energy, Nevada Operations Office, "Announced United States Nuclear Tests," DOE/NV-209 (Rev. 13), May 1993.* (UNCLASSIFIED)

SECTION 1, INTRODUCTION

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

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

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

7. Ponton, Jean, et al., Defense Nuclear Agency, Operation Dominic II, DNA 6027F, 31 January 1983* (UNCLASSIFIED)

SECTION 2, UNDERGROUND TESTING PROCEDURES

8. Radiological Sciences Department, Reynolds Electrical & Engineering Co., Inc., "Standard Operating Procedures," January 1961 - 1968.** (UNCLASSIFIED)

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

10. Liverman, James L., Energy Research and Development Administration, Final Environmental Impact Statement, Nevada Test Site, Nye County, Nevada, ERDA - 1551, September 1977* (UNCLASSIFIED)

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

11. Office of Technology Assessment, Congress of the United States, The Containment of Underground Nuclear Explosions, released 1 November 1989.* (UNCLASSIFIED)

12. McMullan, Frank C., Kaman Sciences Corporation, DoD Nuclear Weapons Effects Tests Summary, Issue 18 for Calendar Years 1962-1987 (U), December 1990.*** (SECRET)

EVENT SUMMARIES AND EACH EVENT SECTION

13. Atomic Energy Commission, Nevada Operations Office, Report of the Test Manager - Operation Nougat (U), 1 September 1961 through 30 June 1962, NVO-5, December 1963.*** (SECRET)

14. Anderson, D. H., et al., Sandia Laboratories, CYPRESS Posttest Summary (U), SC-DR-69-721, November 1969.*** (SECRET)

15. Atomic Energy Commission, Nevada Operations Office, Report of the Test Manager - Operation Flintlock (U), 1 July 1965 through 30 June 1966, NVO-33, March 1967.*** (SECRET)

16. Atomic Energy Commission, Nevada Operations Office, Report of the Test Manager - Operation Latchkey (U), 1 July 1966 through 30 June 1967, NVO-36, May 1968.*** (SECRET)

17. Anderson, W. R., Aerospace Corporation, Operation Flintlock Shot NATIVE MIST Add-On Experiments (U), POR 6227, 4 June 1969.*** (SECRET)

18. Atomic Energy Commission, Nevada Operations Office, NV Completion Report, Operation Bowline (U), 1 July 1968 through 30 June 1969, NVO-66, January 1970.*** (SECRET)

19. Atomic Energy Commission, Nevada Operations Office, NV Completion Report, Operation Emery (U), 1 July 1970 through 30 June 1971, NVO-110, April 1972.*** (SECRET)

20. Coloff, S. G., Air Force Weapons Laboratory, Air Force Experiment, Final Report of Operation CYPRESS, (U), POR 6295, 13 November 1970.*** (SECRET)

21. Smith, Donald R., United States Air Force Academy, AJAX Event, Shot NEAT RIBBON, Project Officers Report, Technical Directors Summary Report (U), POR 3046, 9 February 1970.*** (SECRET)

22. Werkheiser, A. H., et al., U.S. Army Missile Command, Surface Removal Experiment, Operation CYPRESS, Project Officers Interium Report (U), POR 6296, 10 November 1970.*** (SECRET)

23. Whitener, J. E., R&D Associates, Stanton, P. W., FCDNA, Tiano, D. E., NDRC Incorporated, Emergy Series, CAMPHOR Event, Summary Report (U), POR 6580, 23 July 1973.*** (SECRET)

24. Schoengold, C. R., et al., Reynolds Electrical & Engineering Co., Inc., Radiological Effluents Released from Announced U.S. Continental Tests 1961 through 1988, U.S. Department of Energy, DOE/NV 317, May 1990.* (UNCLASSIFIED)

25. REECo Health Protection Department field archives (maintained chronologically and by event) include the following:

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

b. Correspondence.** (UNCLASSIFIED)

c. Reports, including onsite radsafe and offsite PHS event reports.** (UNCLASSIFIED)

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

APPENDIX A

GLOSSARY OF TERMS

Access Drift	A passageway tunnel, usually parallel to the LOS drift, also known as the bypass, cable, reentry, or work drift, also in which cables from various experiments in the LOS pipe were laid on their way to being connected to the downhole cables in the cable alcove, and which was used for access to the main experiment (LOS) drift during construction and recovery phases of a test.
Activation Products	Nuclides made radioactive by neutrons from a nuclear detonation interacting with usually nonradioactive nuclides. Also called "induced activity."
Activity Radioactivity	Decay of radioactive material, usually expressed in disintegrations (of atoms) per minute (dpm).
Advisory Panel	A group of experts formed to advise the Test Manager (and later the Test Controller) concerning operational and safety 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	This included aircraft, facilities, and personnel required for various support functions during testing. Included were cloud sampling, and tracking, radiation monitoring, photography, and transport of personnel and equipment.

Alpha Particle	A particle emitted spontaneously from the nucleus of a radionuclide, primarily a heavy radionuclide. The particle is identical to the nucleus of a helium atom, having an atomic mass of four units and an electric charge of two positive units.
Alpine Miner	A continuous mining machine using a moveable boom with rotating cutting head.
Anticontamination Clothing	Outer clothing worn to prevent contamination of personal clothing, contamination of one's body, and the spread of contamination to uncontrolled areas.
Atmospheric Test Series	Series of U.S. nuclear tests conducted from 1945 through 1962, when most nuclear device detonations were conducted in the atmosphere.
Attenuation	The process by which photons or particles emitted by radionuclides are reduced in number or energy while passing through some medium.
Back	The top (ceiling) of a tunnel.
Background Radiation	There are three meanings for this term. The applicable meaning is determined by the context. The definitions are: 1) The radiations of man's natural environment, consisting of cosmic rays and those radiations which come from the naturally radioactive nuclides of the earth, including those within one's body. 2) A level of radiation (above natural background radiation) that existed in a test area or location prior to a test. 3) Radiation levels extraneous to an experiment (the area exposure rate).

Ballroom	A large alcove in a tunnel used for placement of recording equipment (sometimes referred to as a Dance Hall).
Ball Valve	A rotating valve designed to close off and provide a gas seal in an LOS pipe in less than one second after detonation. It could be pneumatic, hydraulic, or spring driven.
Beta Particle	A negatively charged particle of very small mass emitted from the nucleus of a radionuclide, particularly from fission product radionuclides formed during nuclear detonations. Except for origin, the beta particle is identical to a high-speed electron. This may also be a positively charged particle of equal mass called a positron.
Bypass Drift	See Access Drift.
Bulkhead	Originally a navy term meaning a wall across a ship's hull or a passageway, usually containing a hatch or door. In this context, wall or embankment constructed in a mine or tunnel to protect against earth slides, fire, water, or gas.
Button-Up Activities	Procedures which consist 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	See Access Drift.
Cal-Seal	High-density, high-strength, quick-drying, and resilient commercial sealant.
Cassette	A holder or container for a sample, an experiment, or a group of experiments.

Cavity Invert	See Invert.
Cellar	The excavated, large-diameter initial part of a drilled hole, over which the drill rig is placed and where valving and other equipment are located.
CHAFF	The name of a radiation experiment that used strips of aluminum foil, ejected into the air, for reflecting radar waves or for tracking a descending spacecraft.
Chamber	A natural or man-made enclosed space or cavity.
Check Points or Check Stations	Geographic locations established and staffed to control entry into and exit from restricted areas.
Chimney	A roughly cylindrical volume of broken rock, formed by the collapse of the overburden. Occurs when decreasing gas pressure in the cavity formed by the nuclear detonation cannot support the weight of the rock.
Chromatograph	A piece of equipment used to analyze mixtures of chemical substances by chromatographic absorption.
Cloud Sampling	The process of collecting particulate and gaseous samples from an effluent cloud to determine the amount of total airborne radioactivity and specific radionuclides in the cloud for subsequent analysis of detonation characteristics. This type of sampling usually was accomplished by specially equipped aircraft.
Cloud Tracking	The process of monitoring and determining the drift or movement of an effluent cloud, usually performed by radiation monitoring and visual sighting from aircraft.
Collar	See "Shaft Collar."

Console	A cabinet or panel containing instrumentation for monitoring or controlling electronic or mechanical measurement devices.
Construction Station	The distance in feet along the tunnel from the portal or a particular junction, usually expressed in hundreds of feet plus remaining whole feet. Construction station 350 is expressed as CS 3+50, or simply station 3+50.
Containment	The act of preventing release of any radioactive effluent into the atmosphere or parts of a tunnel complex beyond the stemming and other containment features. It is used in reference to the stemming, TAPS, OBP, or the gas seal plug. An event is said to have been "contained" if no effluent is released to the atmosphere or if no radioactive material is released underground beyond the stemmed portion of the tunnel.
Containment Assessment Drift	Another name for an access or reentry drift.
Contamination	This is defined in two ways as follows: 1) May refer to the presence of fixed or removable radioactive material at a location. Contamination usually is caused by creation, distribution or contact with fission and activation products from a nuclear detonation or that material incorporated with particles from the test environent or device debris. 2) The term may also refer to the deposition on, or spreading of radioactive materials to undesirable locations, personnel, structures, equipment, or other surfaces outside a controlled area.
Controlled Release	Radioactive gas is passed through a filtering system to remove most particulates before the gas is released into

the atmosphere through the tunnel ventilation system.

Crater — This is 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).

DAC — An experiment protection system no longer used. The DNA Auxiliary Closure (DAC) was a system for closing the LOS pipe milliseconds after device detonation.

Dance Hall — A large alcove used for data recording equipment.

DASA — AFSWP became the Defense Atomic Support Agency (DASA) in 1959. See AFSWP and DNA.

D-Day — The term used to designate the day on which a test takes place.

D+1 — The first day after a test event. D+2 is the second day after detonation, D+3 is the third day, etc.

Decontamination — The reduction 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 radioactive decay, or

(3) fixing and covering the contamination to attenuate the radiation emitted.

Device	Nuclear fission (or fission and fusion) materials together with arming, fusing, firing, high-explosive, canister, and diagnostic measurement equipment that have not been configured into an operational weapon.
Dimples	Crumpled section of LOS pipe caused by an explosively driven closure.
Directional Drilling	A rotary drilling technique in which the course of a borehole is controlled by deflection wedges or other means. The technique is used to deflect a deviated borehole back onto course, to bypass an obstruction in the hole, and to reach side areas.
DNA	An acronym for the Defense Nuclear Agency, successor to DASA in 1971.
DoD	An acronym for the U.S. Department of Defense, the federal executive agency responsible for the defense of the United States. Included in this group are the military services and special joint defense agencies.
Dose	A quantity of ionizing radiation energy absorbed by a medium. For a person, dose units are in rem or rad.
Dose Rate	An amount of ionizing radiation energy that an individual or material could absorb per unit of time. Dose rates are usually expressed as rad or rem per hour. Subdivisions of a rad or rem also are used, e.g., mrem/h means millirem per hour. (A millirem equals one thousandth of a rem.)
Dosimeter	A device used to measure radiation doses. Devices worn or carried by individuals are called personnel dosimeters.

dpm	Disintegrations per minute, which is a measure of radioactivity.
Draeger Breathing Apparatus	See Scott-Draeger.
Draeger Multi-Gas Detector	An instrument used to detect toxic gases. A sample of the ambient atmosphere is drawn through a selected chemical reagent tube, which indicates the concentration of a particular toxic gas by changing color.
Dressed Out	Personnel dressed in anticontamination clothing and any associated equipment.
Drift	A horizontal or inclined passageway excavated underground. It is used interchangeably with the term "tunnel" at the NTS.
Drill Hole Designations	These are defined as follows: From the surface - 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 drill hole. From underground locations sample recovery core holes are referred to as RE (Reentry) No. 1, RE No. 2, etc. ("DNRE" means the reentry hole was DNA requested.)
Dry Run	A rehearsal of the functions occurring in the minutes before and during an 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	These are experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. They include measurements of changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Event	See test.
Exoatmospheric	This refers to the area outside the gaseous mass which envelopes the earth.
Explosimeter	A battery-operated detector calibrated to indicate the concentration in the ambient atmosphere of explosive gases and vapors as a percent of the lower explosive limit (LEL) of hydrogen gas (four percent concentration in air) or methane gas (five percent in air).
Exposure	A measure, expressed in roentgens (R), of ionization produced by gamma or x rays in air. (This may also be represented by subdivisions of R; e.g., 1/1000 R = 1 milliroentgen [mR].)
Exposure Rate	Exposure rate is radiation exposure per unit of time, usually per hour, but it may be stated in smaller or larger units (e.g., R/sec, mR/h, R/day).
Face	The end of a tunnel or other excavation that is being worked to advance the tunnel.

FDR	A successful final dry run (FDR) is the last dry run before a test is detonated.
Film Badge	A dosimeter used for the indirect measurement of exposure to ionizing radiation. It generally contains two or three 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 the radiations to be measured. Film packets generally have at least one metal filter or may be in holders with multiple filters. After being worn as a film badge or film dosimeter, films are developed and the degree of darkening (or optical density) measured indicates the radiation exposure. Film dosimeters commonly are used to indicate gamma and x ray exposures, but 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 accompanying release of energy and neutrons. The most important fissionable, or fissile, materials are uranium-235 and plutonium-239. Fission is caused by the absorption of a neutron in the nucleus.
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.
Flap Closure	A pressurized VLOS containment feature.

Forward Control Point	A geographic location in the forward test area, usually adjacent to the closed (or secured) test area.
Front-End Experiments	Those experiments located in the immediate vicinity of the working point.
Full Power Full Frequency (FPFF) Dry Run	This is similar in intent to a mandatory full participation dry run. The FPFF is sometimes combined with the hot dry run (HDR). This run is optional with the device engineer. When this run is conducted, the LOS pipe is under vacuum, telephones and intercoms are disconnected, and tunnel utility and instrumentation power are operated in event-day configuration. All instrumentation is hooked up and operated in event-day configuration (simulators are not used).
Fusion	The combination of two very light nuclei (of atoms) to form a relatively heavier nucleus, with an accompanying release of energy, is called fusion. (It also is also known as thermonuclear fusion.)
Gamma Photons	Electromagnetic radiations of high energy that are emitted from the nuclei of radionuclides. These photons are sometimes referred to as bundles of energy, and usually accompany other nuclear reactions, such as fission, neutron capture, and beta particle emission. Gamma photons, or rays, are identical with x rays of the same energy, except that x rays result from orbital electron reactions rather than being produced in the nucleus.
Gamma Shine	This occurs when a measurable gamma radiation intensity from an approaching radioactive cloud or passing cloud is noted, as opposed to measurements from or in gamma emitting fallout. This also includes gamma radiation scattered

by air molecules, as opposed to direct radiation from a gamma source.

Gas Blocking — Embedding the inner components of cables in epoxy at appropriate locations, such as concrete or epoxy plugs.

Gas Seal Door — A steel door on the portal side of the Gas Seal Plug. It is closed during button up, with about a 10 psi gas pressure applied between the Gas Seal Plug and the Gas Seal Door as an additional reassurance against low-pressure leaks.

Gas Seal Plug — A containment feature within the tunnel complex; generally it is designed for 500°F and 500 psi. The Gas Seal Plug is sometimes referenced as the "hasty plug." This plug is similar to the Overburden Plug, but it is placed closer to the portal and seals off the entire tunnel complex from the portal.

Gate 300 — Permanent security station in Area 6 near the Control Point facilities, at which reentry and recovery personnel wait during execution of an event. After reentry parties were released from this gate, they moved to the FCP and again awaited release.

Geiger-Müeller Counter — An instrument consisting of a Geiger-Müeller tube and associated electronic equipment used to detect, display and sometimes record nuclear radiation levels.

Geophone — An instrument used to detect vibrations in rock or soil. At NTS, it is used remotely to detect rock falls, earth movement, and cavity collapse underground. It provides audible signal and visual display data.

Ground Zero — A term used during atmospheric testing to denote a point on the surface of the ground directly below or coinciding with an atmospheric detonation point (see surface ground zero and zero point).

Grout	A cementing or sealing mixture of cement and water to which sand, sawdust, or other fillers may be added. Some organic epoxy compounds are used where high strength or a controlled setting is desired.
H-hour	"Time zero" or the 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 otherwise noted in seconds or minutes).
Hot Line	A location on the edge of a radex area where personnel exiting remove anticontamination clothing and equipment, are monitored for contamination, and are decontaminated as necessary before release. This term also was used to denote the centerline of a fallout pattern.
HYDRAFRAC (Hydraulic Fracture)	Injection of a dye-containing fluid under pressure into rock which causes areas of the rock to open (i.e., crack) allowing the fluid to permeate the rock. The cracks can be traced upon mining into the area.
Hyvacing	The process of removing debris (from a drill hole or GZ hole) using high-pressure techniques.
Invert	The bottom (floor) of a tunnel or other underground excavation (as in cavity invert).
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 is displaced from its positively charged remaining atom).

Ionizing Radiation	This includes any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its passage through air or matter. Alpha and beta particles produce ion pairs directly, while the electrons of initial ion pairs produced by gamma and x rays in turn produce secondary ionization in their paths. Neutrons may displace a positively charged part of a nucleus, such as a proton or alpha particle which produces secondary ionization.
Isotopes	This refers to 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 (the most abundant) heavy hydrogen (deuterium), and radioactive hydrogen (tritium).
Keyed Concrete Plug	This refers to a concrete plug placed in an excavated area of greater diameter than the shaft or tunnel cross section such that the concrete is poured into the surrounding rock, thus providing greater strength against overpressure from the nuclear detonation.
Leukemia Cluster	An apparent but unexpected or extraordinary group of leukemia cases within some number or group of persons.
Long Line	The longest air sampling pipe into the tunnel which does not connect to the LOS pipe.
LOS Pipe	An evacuated pipe that extends from the device to the test chambers. It may be either horizontal or vertical, and in it are experiment protection devices and experiments.
Mandatory Full Participation (MFP) Dry Run	This is a dry run peculiar to DoD events. Its purpose is threefold: first, to check all experiments with the event site electrical system in its

shot configuration; second, to check for electrical crosstalk between experiments; and third, to operate all recording, timing, and monitoring equipment as closely to shot configuration as is possible. The pipe is under vacuum and the tunnel and portal instrumentation trailers are cleared of personnel. After a successful MFP dry run, all interconnections necessary to place experiments into shot configuration from the MFP configuration are made. Timing, firing, and monitoring system junction boxes are locked and no changes are made except with the express approval of device systems personnel and the Technical Director.

Manhattan Engineer District	The U.S. Army predecessor organization to the U.S. Atomic Energy Commission and the Armed Forces Special Weapons Project.
Manned Stations	Locations inside the closed and secured area which are occupied by authorized personnel during an event.
McCaa Two-Hour Breathing Apparatus	A self-contained respiratory device that supplies two hours of breathing oxygen.
mR	Milliroentgens, a radiation exposure term meaning thousandth of a roentgen (R). (Also, see Exposure.)
mrad/h	A radiation intensity term traditionally used to show that gamma plus beta was being measured.
Mucking	Removal of broken rock from mining operations (also used loosely for drilling operations).
Muffler	An experiment protection component of the HLOS Vacuum System which is designed to break up high-energy flow within the HLOS system.

Noble Gases	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 or other light nuclides - see definition). A developmental nuclear device is not a weapon or weapon component until it can be mated to a delivery system.
Nuclear Device Tests	Tests carried out to supply information required for the design, improvement, or safety aspects of nuclear weapons, and to study the phenomena and effects associated with nuclear explosions.
Nuclear Weapon Tests	Tests that provide development and weapons effects information, and may or may not utilize a deliverable nuclear weapon.
Offsite	Radiation detected offsite is radioactivity occurring outside the Test Range Complex, an area that includes both the Nevada Test Site and the adjacent Nellis Air Force Range.
Onsite	A notation that radioactivity was detected onsite only is made for tests from which there was an unplanned release of radioactivity into the atmosphere that was not detectable beyond

	the boundaries of the Test Range Complex.
Overburden	As used in connection with NTS tunnels, this is the consolidated and unconsolidated rock above a tunnel vertically to the surface; thus, it is the burden of rock over a tunnel.
Overburden Plug	A containment feature within the tunnel complex. It is now a high-strength concrete plug keyed into the tunnel rock near the test location and is generally designed to withstand 1000°F and 1000 psi. It originally was named because it was constructed to represent the same containment strength as the rock above the tunnel, or overburden.
Party Monitors	Radiation (Radsafe) monitors assigned to reentry and recovery parties or groups.
Portal Recording Station	The Portal Recording Station (PRS) is a building located outside of the tunnel where fiber optic cables are terminated and event data is recorded.
ppm	The term parts per million is used when determining concentrations of toxic gases or other materials. It refers to either relative weight, such as micrograms of a material per gram of medium, or relative volume, such as cubic centimeters or milliliters per cubic meter.
Privacy Act	The Privacy Act of 1974 is part of Public Law 93-579. This is an Act to amend Title 5, U.S. Code, by adding Section 552a, which is to safeguard individual privacy from the misuse of federal agency records, to provide that individuals be granted access to records concerning them which are maintained by federal agencies, to establish a Privacy Protection Study Commission, and for other purposes.

rad	An acronym for "radiation absorbed dose," a unit of absorbed dose of ionizing radiation. A dose of one rad means the absorption of 100 ergs of energy from ionizing radiation per gram of absorbing material (e.g., body tissue).
Radex Area	A radiation exclusion (radex) area is any area which is controlled for the purpose of protecting individuals from exposure to radiation and/or radioactive materials.
Radiation Exposure	Exposure to radiation may be described by a number of terms. The type of radiation one is exposed to is important in establishing doses. External exposure can be from beta particles, neutrons, gamma and x rays; internal exposure is received from radionuclides deposited within the body which may emit alpha, beta, gamma, or radiation and irradiate various body organs. (See Dose and Exposure.)
Radioactive Effluent	This includes the radioactive material, steam, smoke, dust, and other particulate or gaseous 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 various elements, as opposed to stable nuclides. (See Isotopes).
Recovery Operations	Process of finding and removing experiments, by-products, or data from the test area after a test event.
Red Shack	An underground (usually) intermediate point provided for the device labora-

	tory's use in checking out and exercising the arming and firing system.
Reentry Drift	See Access Drift.
rem	An acronym for "roentgen equivalent man or mammal." A rad multiplied by the quality factor (QF) of a particular radiation equals the rem dose. Current QF values are one for x, gamma, and beta radiations, 10 for all neutrons, and 20 for alpha particles.
Rib	This refers to the side of the drift. The right or left rib is determined with one's back to the portal.
Rock Bolting	A method whereby rock bolts (i.e., threaded steel rods) are inserted into a drilled hole to pin the rock to the rib or back and reinforce the tunnel walls. The bolts are driven into the wall perpendicular to the shaft. The ends project far enough for end plates to solidify the structure.
roentgen	A special unit of exposure. It is defined precisely as that 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} coulombs 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. During these tests, elements of the conventional high-explosive portions of the devices were detonated to simulate accidental damage and to determine the potential for this 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 and constructed of sandbags to help contain underground detonations and minimize damage to underground workings.
Sandia Auxiliary Closure (SAC)	A device used to seal an HLOS pipe after a nuclear detonation.
Scatterer Station	A point along an LOS pipe where the radiation flux is deflected into an area off the LOS pipe as required for the testing or exposure of scatterer area experiments.
Scientific Station	The distance in feet along the HLOS pipe measured from the zero point. These distances are generally expressed in whole numbers or to the nearest complete hundredths of feet (if fractional). Scientific Station 650 is expressed as SS 6+50; Scientific Station 390.65 is expressed as SS 3+90.65.
Scott-Draeger Self-Contained Breathing	This includes a self-contained recirculating unit, complete with "full view" apparatus facepiece, compressed oxygen cylinder, breathing bag, carbon dioxide absorber, and pressure demand regulator. It is used when an extended exposure to an extremely hazardous or oxygen deficient atmosphere, or both, is required. This unit is capable of sustaining the wearer, under normal usage, for four to four and one-half hours; however, pertinent approved schedules limit NTS use to two hours.
Seismic Motion	Earth movement caused by an underground nuclear detonation, similar to that of a minor earthquake.
Shaft	A long narrow passage sunk into the earth, usually vertically, but inclined for some mining operations. 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.

Shaker Screen — The screen attached to a vibrating (shaker) table where rocks and debris are separated from the recirculating mud/water mixture during drilling operations.

Shielding Walls — Walls or barriers used to protect equipment or instrumentation from heat, blast, and radioactivity.

Shoe — A concrete plug formed at the bottom of a cemented, cased hole.

Sidetracking — The process of drilling off the main (or predrilled) drill hole to a predetermined location.

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. (See Mucking.)

Spalling — Rock disintegration by evidenced flaking, chipping, peeling, or loosening of layers on the outside edges. It may be caused immediately after detonation by rock stressing near the detonation point. It also may result 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.

Spoolex Assembly — The housing, containing experiments, that was placed over the VLOS pipe.

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.

Survey — In the tunnels, a survey might include taking radiation readings with a portable instrument, checking for the presence of an explosive mixture with an MSA explosimeter or GPK, determining toxic gas levels with Draeger tubes, and/or checking for tunnel hazard and damage (also called a "walkthrough" or "walk-out"). Radsafe personnel made the radiation surveys. Radsafe or industrial hygiene personnel (both in the REECo Environmental Sciences Department) monitored LEL level and toxic gas levels, and tunnel mining and construction personnel performed walk throughs usually accompanied by Radsafe and/or industrial hygiene support personnel. (See tunnel walk-out.)

TAPS — The tunnel and pipe seal is 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 later arriving debris. It contains a massive steel door which closes after ground shock passes to form a 1000°F and 1000 psi seal. The TAPS also includes the high-strength concrete plug which surrounds the metallic shroud of the door.

Test — The preparations for, and actual testing of, a nuclear device. This includes arming and firing, detonation, concurrent measurements and effects, and later measurements and studies.

Test Chamber — A section of the LOS pipe in which experiments are placed. It may or may not be enlarged, depending upon the test design.

Test Controller	A DOE official designated by the Manager, Nevada Operations Office, to assume responsibility for the field operations involved in conducting a nuclear test at the Nevada Test Site.
Testing Organizations	Organizations conducting nuclear tests at the NTS (see DoD, DNA, LASL, LLL, and SL).
Thermal Shield Plug	A bulkhead built to close off a drift (usually the LOS pipe drift) that protects equipment and instruments on the portal side of the bulkhead. Construction and containment features of the bulkhead are determined by the nature of the event.
Tonopah Test Range	TTR is located in the northwest corner of Nellis Air Force Range near Tonopah, Nevada.
Trailer Park	Areas near a tunnel portal or on the Mesa where instrumentation or instrumentation support trailers are parked.
Tunnel	At NTS, this refers to a horizontal underground excavation driven on a predetermined line and grade to some specific target.
Tunnel Access	This refers to the entering of a tunnel or tunnel complex upon approval of the Test Controller or Test Director during test operations, or upon approval of the Tunnel Superintendent during routine operations.
Tunnel and Pipe Seal	See TAPS
Tunnel Complex	This includes the complete set of underground workings and support equipment comprising one tunnel test area.
Tunnel Walk-Out	A visual, walking inspection of the tunnel or tunnel complex, usually performed as a part of the initial reentry after a detonation, to check for damage

and hazards prior to allowing general access to the underground workings.

Turntube	In the tunnels at the NTS, this refers to a crawlway through a containment barrier (i.e., bulkhead, blast wall, or plug.) After an event, the crawlway is used for access through the barrier until the manway can be opened.
Type N Canisters	These canisters are used with face masks to absorb carbon monoxide.
Underground Structures Program	This refers to the fabrication and construction of test structures underground for the purpose of detonation effects evaluation.
User	Any organization conducting nuclear 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, gases, 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. They include measuresments 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 for the purpose of evaluating weather conditions and forecasts on

event day, and making decisions on any operational schedule changes necessary for safety reasons.

Work Drift	See Access Drift.
Working Point	The location in the emplacement hole centered in the nuclear device.
Workings	An excavation or group of excavations made in mining, quarrying, or tunneling, used chiefly plural, such as "the workings extended for miles underground."
x rays	Electromagnetic radiations produced by orbital electron reactions, as opposed to emission of gamma photons by nuclei of atoms. Otherwise, x rays are identical with gamma photons of the same energy.
Yield	The total effective energy released by a nuclear detonation. It is usually expressed in terms of 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. Actual distribution depends upon the medium in which the explosion occurs and upon the type of weapon or nuclear device.
Zero Point	The location of the center-of-burst of a nuclear device at the instant of detonation. The zero point in tests covered by this volume is always below ground.

APPENDIX B

ABBREVIATIONS AND ACRONYMS

The abbreviations and acronyms in the following list are used in this seventh volume of the DoD UNTPR reports. Additional information and definitions may be found in the text and in the Glossary of Terms.

AA	Agbabian Association
AEC	Atomic Energy Commission
AEC/NVOO	AEC Nevada Operations Office
AERO	Aerospace Corporation
AES	Auxiliary Experiment Station
AFC	Philco-Ford Corporation
AFSC	Air Force Systems Command
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AFWL	Air Force Weapons Laboratory
ALOO	Albuquerque Operations Office
AMC	Army Material Command
AMICON	Army Missile Command
APL	Applied Physics Laboratory
ASR	Alcove splice rack
AVCO	AVCO Corporation
AWRE	Atomic Weapons Research Establishment
BAC	Boeing Aircraft Corporation

BMO	Ballistics Missile Office
BRL	Ballistics Research Laboratory
BSD	Ballistics Systems Division(of TRW)
BTL	Bell Telephone Laboratories
CAPCo	Corrales Applied Physics Company
CASES	Merritt Cases, Inc.
CC	Crosscut
CCTV	Closed-circuit television
CDC	Centers for Disease Control (formerly the Center for Disease Control)
CEP	Containment Evaluation Panel
CH	Cable hole
CIC	Coordination and Information Center
CO	Carbon monoxide
CORRTEX	Continuous Reflectometry for Radius Time Experiments
CP	Control Point
CP-1	Control Point, Building 1
CP-2	Control Point, Building 2
CP-9	Control Point, Building 9
CTO	Continental Test Organization
DAC	Douglas Aircraft Corporation
DAC	DNA Auxiliary Closure
DASA	Defense Atomic Support Agency
DMA	Division of Military Application

DNA	Defense Nuclear Agency
DNRE	DNA Reentry
DoD	Department of Defense
DOE	Department of Energy
DOE/NV	Department of Energy, Nevada Operations Office
dpm	Disintegrations per minute
DPP	Drift Protection Plug
Draper	C.S. Draper Laboratory
DRI	Denver Research Institute
EDAC	Engineering Decision Analysis Company
EG&G	EG&G, Inc. (formerly Edgerton, Germeshausen, and Grier)
EMP	Electromagnetic pulse
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ERDL	U.S. Army Research & Development Laboratories
ES	Experiment Station
ESD	Environmental Sciences Department, REECo
ESSA/C&GS	Environmental Science Services Administration/Coast & Geodetic Survey
ETI	Effects Technology, Incorporated
F&S	Fenix & Scisson, Inc.
FAC	Fast Auxiliary Closure
FCDASA	Field Command, Defense Atomic Support Agency
FCDNA	Field Command, Defense Nuclear Agency

FCP	Forward Control Point
FCT	Field Command Test
FCTC	Field Command, Test Construction (Division of Test Directorate)
FCTE	Field Command, Test Engineering Division
FCTK	Field Command, Test Containment Division
FCTO	Field Command, Test Operations Division
FCTP	Field Command, Test Plans & Analysis Division
FCTS	Field Command, Test Office of Safety Engineer
FCTT	Field Command, Technical Directors Division
FDPP	Facility Drift Protection Plug
FDR	Final dry run
FPFF	Full-power-full-frequency (dry run)
FWW	Fighter Weapons Wing
GA	General Atomic Corporation
GE	General Electric Corporation
GEOTECH	Geotechnical Corporation
GM	Geiger-Müeller
GRC	General Research Corporation
GSAC	Gas Seal Auxiliary Closure
GSD	Gas Seal Door
GSP	Gas Seal Plug
GZ	Ground zero
H&N	Holmes & Narver, Inc.

HAC	Hughes Aircraft Co.
HDL	Harry Diamond Laboratory
HDR	Hot Dry run
HE	High explosives (conventional)
HEPA	High-efficiency particulate aerosol
HFR	High fluence recovery
HLOS	Horizontal line-of-sight
HQ/DASA	Headquarters, Defense Atomic Support Agency
HSG	High-strength grout
IRT	Intelcom Rad Tech
ISAFAF	Indian Springs Air Force Auxiliary Field (formerly Indian Springs Air Force Base)
ISAFB	Indian Springs Air Force Base
JAYCOR	Jaycor Corporation (derived from J.A. Young Corporation)
JCS	Joint Chiefs of Staff
KAFB	Kirtland Air Force Base
KN	Kaman Nuclear
KOA	Ken O'Brien Associates
KSC	Kaman Sciences Corp. (formerly Kaman Nuclear)
kt	Kilotons
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory
LEL	Lower explosive limit
LLC	Limited-life components

LLL	Lawrence Livermore Laboratory
LLNL	Lawrence Livermore National Laboratory
LMAFS	Lookout Mountain Air Force Station
LMSC	Lockheed Missile and Space Corporation
LOS	Line-of-sight
LPARL	Lockheed Palo Alto Research Laboratory
LRL	Lawrence Radiation Laboratory
LTBT	Limited Test Ban Treaty
LVFO	Las Vegas Field Office
M&D	MAC and DAC
MAC	Mechanical Auxiliary Closure
MDAC	McDonald Douglas Aircraft Corporation
MDAC	McDonnel Douglas Astronautics Corporation
MDR	Mandatory Dry Run
MED	Manhattan Engineer District
MFP	Mandatory full-participation
MFP/FPPF	Mandatory full-participation/full-power full-frequency
MOLEC	Moleculon Research Corporation
MPC	Maximum permissible concentration
mR	Milliroentgen
mrad	Millirad
MRC	Mission Research Corporation
mrem/qt	Millirem per quarter

mrem/yr	Millirem per year
mR/h	Milliroentgens per hour
MSA	Mine Safety Appliances
MSD	Mandatory Signal Dry Run
MSL	Mean sea level
NAFB	Nellis Air Force Base
NOAA/ARL	National Oceanic and Atmospheric Administration, Air Resources Laboratory
NO_2	Nitrogen dioxide
$NO+NO_2$	Nitric oxide plus nitrogen dioxide
NPG	Nevada Proving Ground
NRDS	Nuclear Rocket Development station
NSC	National Security Council
NTIS	National Technical Information Service
NTS	Nevada Test Site
NTSO	Nevada Test Site Organization
NV	DOE Nevada Operations Office
NVOO	Nevada Operations Office
NWET	Nuclear weapons-effects test
OBP	Overburden plug
OMA	Office of Military Application
PA	Picatinny Arsenal
Pan Am	Pan American World Airways
pCi/m^3	Picocuries per cubic meter

PDT	Pacific Daylight Time
PI	Physics International
ppm	Parts per million
PRS	Portal Recording Station
PS	Postshot
psi	Pounds per square inch
PST	Pacific Standard Time
QF	Quality factor
R&D	Research and development
rad	Radiation absorbed dose
rad/h	Radiation absorbed dose per hour
Radsafe	Environmental Sciences Department (formerly Radiological Safety Department), REECo
radsafe	Radiological safety, in general
RAGS	Remote Area Gas Sampling
RAMP-4	Multichannel, hard-wire linked, remote area gamma monitoring telemetry system
RAMS	Remote area monitoring system
RCG	Radioactivity concentration guide
RDS	Remote Data Station
REECo	Reynolds Electrical & Engineering Company, Inc.
rem	Roentgen equivalent man or mammal
R/h	Roentgens per hour
RL	Radiolink Telemetry
RMG	Rock-matching grout

RMS	Radector Monitoring Station
ROSES	Recorder and Oscilloscope Sealed Environmental System
RPG	Radiation protection guide
SAC	Sandia Auxiliary Closure
SAI	Science Applications, Inc. (became Science Applications International Corp., SAIC on 1 August 1984)
SAMSO	Space and Missile Systems Organization
SC	Sandia Corporation
SCBA	Self-contained breathing apparatus
SDR	Signal dry run
SEAS	SeaSpace Systems, Incorporated
SFOO	Santa Fe Operations Office
SGEMP	Source Generated Electromagnetic Pulse
SGZ	Surface ground zero
SL	Sandia Laboratories
SLA	Sandia Laboratories, Albuquerque
SNL	Sandia National Laboratories
SOP	Standard operating procedures
SRD	Secret Restricted Data
SREMP	Source Region Electromagnetic Pulse
SRI	Stanford Research Institute
SRII	Stanford Research Institute International
SSPO	Strategic Systems Project Office (Navy)

SSD	Space Systems Division
SSS	Systems, Science, and Software
STARSAT	Source Generated Electromagnetic Pulse Test, Analysis and Research Satellite
STU	Special Test Unit
SWRHL	Southwest Radiological Health Laboratory
TAC	Tactical Air Command
TAPS	Tunnel and Pipe Seal
TBD	Test Director's Barricade
TC	Test chamber
TCDASA	Test Command, Defense Atomic Support Agency
TCDNA	Test Command, Defense Nuclear Agency
TEP	Test Evaluation Panel
TGD	Test Group Director
TGS	Test Group Staff
TID	Test Instrumentation Development
TLD	Thermoluminescent dosimeter
TMB	Test Manager's Barricade
TNT	High explosive chemical, (2,4,6-trinitrotoluene)
TOA	Time-of-Arrival
TRI	Technical Representatives, Incorporated
TRW	TRW Systems, Incorporated
TSP	Thermal Shield Plug
TTR	Tonopah Test Range

UCRL	University of California Radiation Laboratory
USAF	United States Air Force
USAPC	United States Army Pictorial Center
USC&GS	United States Coast & Geodetic Survey
USGS	United States Geological Survey
USPHS	United States Public Health Service
VA	Veterans Administration
VLOS	Vertical line-of-sight
WEBS	Weapons-effects buoy systems
WERL	Western Environmental Research Laboratory
WES	Waterways Experiment Station
WETG	Weapons Effects Test Group
WP	Working point
WSI	Wackenhut Services, Incorporated
WTD	Weapons Test Division

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

NTSO-0101-01

CHAPTER 0101 THE NEVADA TEST SITE ORGANIZATION (NTSO)

0101-01 General

011 The Nevada Test Site

The Nevada Test Site (NTS) is a facility provided by the Atomic Energy Commission and managed by the AEC Nevada Operations Office (NV). The NTS supports the field test programs of the AEC and its contractors, the Department of Defense, and others authorized to be conducted at the NTS.

012 The Nevada Test Site Organization (NTSO)

The Nevada Test Site Organization (NTSO) includes AEC, DOD, Laboratory, contractor, agency and organizational personnel who participate in, or provide support for, test operations at the Nevada Test Site (NTS). The Manager, NV, as the Site Manager, heads the NTSO (see Appendix "A").

0101-02 Organizational Concept and Policies

021 Nevada Test Site Organization (NTSO)

The Nevada Test Site Organization is a continuing task organization whose composition may be readily changed in response to the needs and technical objectives of the test program.

022 The NV staff, for the Manager, provides for the approval and coordination of program proposals, approvals for project support, funding and/or authority for financial agreement, legal counsel, contract authority and administration, engineering, accounting, classification and security policy and guidance, safety policy and guidance, environmental safety analyses, industrial relations, and public information policy to the NTSO.

023 Test execution shall conform to statutory, regulatory, and other responsibilities in accordance with delegations to the Manager, NV, by the General Manager of the Atomic Energy Commission.

024 Technical users are allowed maximum technical latitude in the conduct of their scientific programs and are responsible for their technical readiness.

Revised: March 30, 1972

025 User groups may be assigned areas in which to conduct their operations and exercise technical control subject to operational site coordination and control exercised by the Site Manager or, during a Test Execution Period, the Test Controller.

026 The Site Manager, NTS, has the authority to approve or disapprove the field execution of tests that have been approved by Headquarters AEC. During the Test Execution Period, authority to proceed with or postpone the field execution of approved activities or tests is delegated to the Test Controller in accordance with his Delegation of Authority from the Manager, NV.

0101-03 Responsibilities

031 The Site Manager is responsible for administering the NTS, for all preparations required for the safe execution of programs and projects at the NTS and for providing construction and logistic support services and facilities required to support the technical users.

032 The Test Controller is responsible to the Manager, NV, for the conduct of those experiments and test events in the testing program to which he is assigned by the Manager, NV.

033 The Deputy, Military Matters (Director, Test Directorate, FCDNA), serves as deputy for the Site Manager on operational, administrative and support matters pertaining to all DNA activities.

034 The Scientific Manager's Advisory Panel is chaired by a Scientific Advisor designated by the Manager, NV, as nominated by the technical user. Members of the panel provide advice on matters relative to on- and off-site safety.

035 The Test Group Directors (TGD) are assigned by the scientific sponsor to direct the fielding and technical aspects of experiments and tests. He reports to the Test Controller on operational matters relating to test execution.

036 The Director, Logistics Support, is responsible for the direction and control of construction and logistical support activities at the NTS and during Test Execution Periods, supports the Test Controller directly in the field execution of experiments and test events.

037 The Director, Operational Support, aided by the Operations Control Group and Special Staff assigned from NV as required, provides advice, assistance and serves as principal operations coordinator for the Site Manager and during the Test Execution Period, as Director of Operations for the Test Controller.

038 The Control Point Coordinator assures the availability in the OCC of facilities and equipment for the control and coordination of NTS operational activities.

Revised: March 30, 1972

039 The Test Operations Officer supervises the preparation of the Test Controller's operation and security plan and other required plans as directed. He coordinates preparations for the test execution and forward area support. During the Test Execution Period, he assists the Director of Operations in supervising and coordinating execution of the operations and security plan as directed by the Test Controller.

040 The Test Liaison Officer provides oral communication of test-related operational information from the operational control point (NTS) to NV and the Test Operations Center (TOC) AEC HQ during the Test Execution Period.

041 The FCDNA, Test Construction Division, is responsible for directing DOD furnished support.

042 The Technical Program Groups consist of organizational units and staff to satisfy the program objectives of their parent organizations.

Revised: March 30, 1972

APPENDIX D

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

NTSO-05240-01

Chapter 0524 RADIOLOGICAL SAFETY

0524-01 Radiological Safety

011 Purpose

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

012 Responsibilities

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

b. Test Manager. The Test Manager is responsible for the protection of participating personnel and off-site population from radiation hazards associated with activities conducted at the NTS. By mutual agreement between the Test Manager and a scientific user, control of radiological safety within the area assigned for a particular activity may be delegated to the user's Test Group Director during the period of time when such control could have a direct bearing on the success or failure of the scientific program. The provisions of AEC Manual Chapter 8401 shall apply to reactor tests or sustained reactor operations.

c. Test Group Director. Whenever operational radiological safety control is delegated to a Test Group Director under provisions of 012a above, he is responsible to the Test Manager for establishment and implementation of radiological safety criteria within the assigned area. He will be responsible for submitting a detailed radiological safety operational plan to the

Revised: February 9, 1968

Test Manager for review and concurrence. This plan shall be submitted as Standard Operating Procedures (SOP) to cover all routine operations. Variances from the SOP for non-routine operations shall be presented to the Test Manager for review and concurrence. Upon termination of need for the Test Group Director to retain radiological safety control within an assigned area, the Test Group Director will be relieved of radiological safety responsibility.

d. Director, Nevada Test Site Support Office (NTSSO). Supervises the approved NTS on-site radiological safety programs, except for those periods in which operational control of specified areas may be delegated to others (i.e., Test Manager, Test Group Directors, etc.).

e. Radiological Safety Advisor. The NTSO Radiological Safety Advisor is responsible to the Test Manager for staff supervision of radiological safety policies and procedures at the NTS. Monitoring of the radiological safety policies and direction of procedures at NTS, during non-operational periods, rests with the Director, NTSSO.

f. Chief, Safety Branch (SB), NTSSO. The Chief, Safety Branch, NTSSO, will be responsible to the Director, NTSSO, for conducting field inspections at the NTS to assure that NTS contractors execute safety programs in accordance with approved safety procedures and plans as well as with AEC and NVOO directives. Recommends corrective actions where necessary. Assures that radioactive waste management and disposal are accomplished in accordance with approved procedures. Coordinates and administers NTS activities relative to the Radiological Assistance Program. Provides day-by-day coordination and monitoring of NTS radiological safety activities, except for those periods during which operational control of specified areas may be delegated to others.

g. Director, Safety Evaluation Division (SED), NVOO. Provides for staff development of safety programs of NVOO for use at NTS. Develops safety programs which are coordinated with NTSSO and site user agencies and organizations to meet public and operational safety requirements for the conduct of nuclear detonations, reactor test programs, chemical explosives tests, or other NVOO activities. Arranges for radiological studies as may be appropriate.

Revised: February 9, 1968

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. Routing 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.

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.

Revised: February 9, 1968

m. Other. Other responsibilities as well as more detailed versions of the above, are spelled out in NTSO-0103.

0524-02 Organization

The chart showing the organizational relationship of the NTS radiological safety activities is shown in Figure 1 on the following page.

0524-03 Definitions

a. Radiological Safety. The protection of personnel, population groups, and the environment from the effects of ionizing radiation.

b. Ionizing Radiation. Electromagnetic radiation (consisting of photons) or particulate radiation (consisting of electrons, neutrons, protons, etc.) usually of high energy, but in any case capable of ionizing air, directly or indirectly.

c. NTS. The Nevada Test Site.

d. On-Site. Areas within the NTS boundaries, including Mercury.

e. Certified Monitor. Any person certified to the Test Manager or his designated representative as a qualified monitor by a Test Group Director or the Radiological Safety Representative of the radiological safety services.

f. Radiation Exclusion Area (Radex). A limited access area designated and posted for radiological safety purposes.

g. Controlled Area. Any area to which access is controlled by the AEC or AEC contractors.

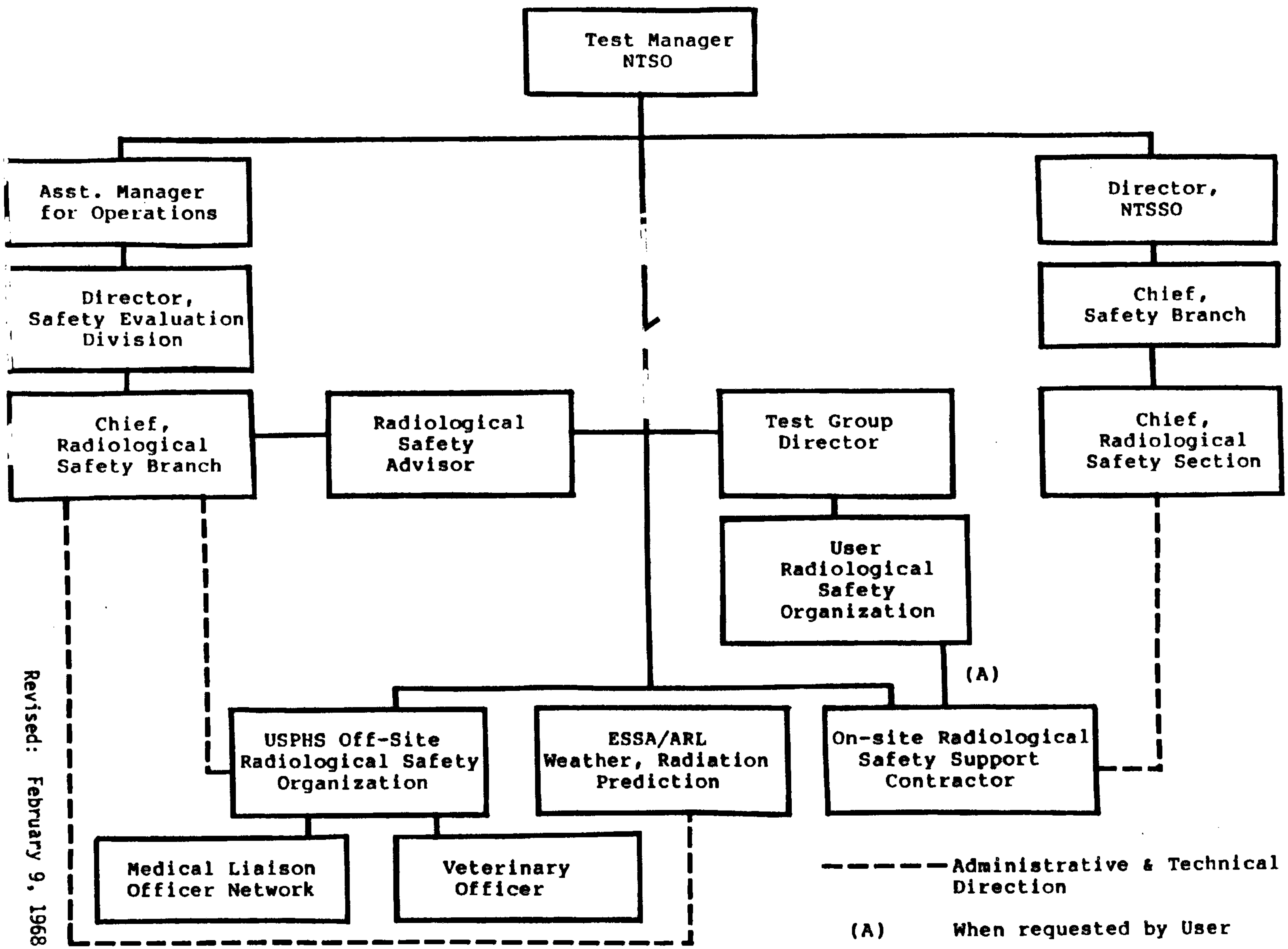
h. User. Any organization or test participant having a NVOO-approved technical program for conduct at the NTS.

i. Radiation Incident. Any alleged radiation accident, which if true, could result in property damage or loss, injury, over exposure, or excessive release of radioactive materials.

j. Roentgen. A unit of exposure to X or gamma radiation. 1 mR (one milliRoentgen) is one-one thousandth of one Roentgen.

k. Rad. A unit of absorbed dose equivalent to 100 ergs/gram.

Revised: February 9, 1968



Revised: February 9, 1968

I. RADIATION PROTECTION STANDARDS FOR INDIVIDUALS IN CONTROLLED AREAS [1]

A. Radiation from sources external to the body

Type of Exposure	Period of Time	Dose (rem)
Whole body, head and trunk, active blood-forming organs Gonads, or lens of eye.	Accumulated dose	5 (N-18) [2]
	Calendar quarter [3]	3 [4]
	Year	30
Skin of whole body and thyroid	Calendar quarter [3]	10 [4]
	Year	75 [4]
Hands, and forearms, feet and ankles	Calendar quarter [3]	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 ograns	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 accured 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 to 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.

Revised: February 9, 1968

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	0.17
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 annes 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.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Actinium (89)	AC 227	S	$2x10^{-12}$	$6x10^{-5}$	$8x10^{-14}$	$2x10^{-6}$
		I	$3x10^{-11}$	$9x10^{-3}$	$9x10^{-13}$	$3x10^{-4}$
	AC 228	S	$8x10^{-8}$	$3x10^{-3}$	$3x10^{-9}$	$9x10^{-5}$
		I	$2x10^{-8}$	$3x10^{-3}$	$6x10^{-10}$	$9x10^{-5}$
Americium (95)	Am 241	S	$6x10^{-12}$	$1x10^{-4}$	$2x10^{-13}$	$4x10^{-6}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$2x10^{-5}$
	Am 243	S	$6x10^{-12}$	$1x10^{-4}$	$2x10^{-13}$	$4x10^{-6}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
Antimony	Sb 122	S	$2x10^{-7}$	$8x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
	Sb 124	S	$2x10^{-7}$	$7x10^{-4}$	$5x10^{-9}$	$2x10^{-5}$
		I	$2x10^{-8}$	$7x10^{-4}$	$7x10^{-10}$	$2x10^{-5}$
	Sb 125	S	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$3x10^{-8}$	$3x10^{-3}$	$9x10^{-10}$	$1x10^{-4}$
Argon (18)	A 37	Sub[2]	$6x10^{-3}$	....	$1x10^{-4}$	....
	A 41	Sub	$2x10^{-6}$	....	$4x10^{-8}$	....
Arsenic (33)	As 73	S	$2x10^{-6}$	$1x10^{-2}$	$7x10^{-8}$	$5x10^{-4}$
		I	$4x10^{-7}$	$1x10^{-2}$	$1x10^{-8}$	$5x10^{-4}$
	As 74	S	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$5x10^{-5}$
		I	$1x10^{-7}$	$2x10^{-3}$	$4x10^{-9}$	$5x10^{-5}$
	As 76	S	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$6x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
	As 77	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$8x10^{-5}$
Astatine (85)	At 211	S	$7x10^{-9}$	$5x10^{-5}$	$2x10^{-10}$	$2x10^{-6}$
		I	$3x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$7x10^{-5}$
Barium (56)	Ba 131	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
	Ba 140	S	$1x10^{-7}$	$8x10^{-4}$	$4x10^{-9}$	$3x10^{-5}$
		I	$4x10^{-8}$	$7x10^{-4}$	$1x10^{-9}$	$2x10^{-5}$
Berkelium (97)	Bk 249	S	$9x10^{-10}$	$2x10^{-2}$	$3x10^{-11}$	$6x10^{-4}$
		I	$1x10^{-7}$	$2x10^{-2}$	$4x10^{-9}$	$6x10^{-4}$
Beryillium (4)	Be7	S	$6x10^{-6}$	$5x10^{-2}$	$2x10^{-7}$	$2x10^{-3}$
		I	$1x10^{-6}$	$5x10^{-2}$	$4x10^{-8}$	$2x10^{-3}$
Bismuth (83)	Bi 206	S	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
		I	$1x10^{-7}$	$1x10^{-3}$	$5x10^{-9}$	$4x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Bi 207	S	$2x10^{-7}$	$2x10^{-3}$	$6x10^{-9}$	$6x10^{-5}$
		I	$1x10^{-8}$	$2x10^{-3}$	$5x10^{-10}$	$6x10^{-5}$
	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	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-3}$	$4x10^{-5}$
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 252	S	$2x10^{-11}$	$7x10^{-4}$	$7x10^{-13}$	$2x10^{-5}$
		I	$1x10^{-10}$	$7x10^{-4}$	$4x10^{-12}$	$2x10^{-5}$
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	$1x10^{-8}$	$1x10^{-3}$	$4x10^{-10}$	$4x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I		Table II	
			Column I Air (μc/ml)	Column 2 Water (μc/ml)	Column I Air (μc/ml)	Column 2 Water (μc/ml)
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	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^{-8}	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}	3×10^{-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}
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}
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}

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (µc/ml)	Table I Column 2 Water (µc/ml)	Table II Column 1 Air (µc/ml)	Table II Column 2 Water (µc/ml)
	Er 171	S	$7x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Europium (63)	Eu 152	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	(T/2.=9.2 hrs)	I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	Eu 152	S	$1x10^{-8}$	$2x10^{-3}$	$4x10^{-10}$	$8x10^{-5}$
	(T/2=13 yrs)	I	$2x10^{-8}$	$2x10^{-3}$	$6x10^{-10}$	$8x10^{-5}$
	Eu 154	S	$4x10^{-9}$	$6x10^{-4}$	$1x10^{-10}$	$2x10^{-5}$
		I	$7x10^{-9}$	$6x10^{-4}$	$2x10^{-10}$	$2x10^{-5}$
	Eu 155	S	$9x10^{-8}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
		I	$7x10^{-8}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
Fluorine (9)	F 18	S	$5x10^{-6}$	$2x10^{-2}$	$2x10^{-7}$	$8x10^{-4}$
		I	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$5x10^{-4}$
Gadolinium (64)	Gd 153	S	$2x10^{-7}$	$6x10^{-3}$	$8x10^{-9}$	$2x10^{-4}$
		I	$9x10^{-8}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Gd 159	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$8x10^{-5}$
Gallium (31)	Ga 72	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
Germanium (32)	Ge 71	S	$1x10^{-5}$	$5x10^{-2}$	$4x10^{-7}$	$2x10^{-3}$
		I	$6x10^{-6}$	$5x10^{-2}$	$2x10^{-7}$	$2x10^{-3}$
Gold (79)	Au 196	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$6x10^{-7}$	$4x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
	Au 198	S	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$5x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$5x10^{-5}$
	Au 199	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
Hafnium (72)	Hf 181	S	$4x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$7x10^{-5}$
		I	$7x10^{-8}$	$2x10^{-3}$	$3x10^{-9}$	$7x10^{-5}$
Holmium (67)	Ho 166	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
Hydrogen (1)	H3	S	$5x10^{-6}$	$1x10^{-1}$	$2x10^{-7}$	$3x10^{-3}$
		Sub	$2x10^{-3}$	....	$4x10^{-5}$	....
Indium (49)	In 113m	S	$8x10^{-6}$	$4x10^{-2}$	$3x10^{-7}$	$1x10^{-3}$
		I	$7x10^{-6}$	$4x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
	In 114m	S	$1x10^{-7}$	$5x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$2x10^{-8}$	$5x10^{-4}$	$7x10^{-10}$	$2x10^{-5}$
	In 115m	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-6}$	$1x10^{-2}$	$6x10^{-8}$	$4x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/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}	1×10^{-9}	3×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-3}	2×10^{-11}	4×10^{-7}
		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}	1×10^{-10}	7×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	2×10^{-9}	1×10^{-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}	2×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (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}	....
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}

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
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}
	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}
Molydbenum (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}
Nioblum (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}

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Osmium (76)	Os 185	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$5x10^{-8}$	$2x10^{-3}$	$2x10^{-9}$	$7x10^{-5}$
	Os 191m	S	$2x10^{-5}$	$7x10^{-2}$	$6x10^{-7}$	$3x10^{-3}$
		I	$9x10^{-6}$	$7x10^{-2}$	$3x10^{-7}$	$2x10^{-3}$
	Os 191	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
	Os 193	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$9x10^{-9}$	$5x10^{-5}$
Palladium (46)	Pd 103	S	$1x10^{-6}$	$1x10^{-2}$	$5x10^{-8}$	$3x10^{-4}$
		I	$7x10^{-7}$	$8x10^{-3}$	$3x10^{-8}$	$3x10^{-4}$
	Pd 109	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
Phosphorus (15)	P 32	S	$7x10^{-8}$	$5x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
		I	$8x10^{-8}$	$7x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
Platinum (78)	Pt 191	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
	Pt 193m	S	$7x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
		I	$5x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
	Pt 197m	S	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
		I	$5x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$9x10^{-4}$
	Pt 197	S	$6x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Plutonium (94)	Pu 238	S	$2x10^{-12}$	$1x10^{-4}$	$7x10^{-14}$	$5x10^{-6}$
		I	$3x10^{-11}$	$8x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
	Pu 239	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$5x10^{-6}$
		I	$4x10^{-11}$	$8x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
	Pu 240	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$5x10^{-6}$
		I	$4x10^{-11}$	$8x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
	Pu 241	S	$9x10^{-11}$	$7x10^{-3}$	$3x10^{-12}$	$2x10^{-4}$
		I	$4x10^{-8}$	$4x10^{-2}$	$1x10^{-9}$	$1x10^{-3}$
	Pu 242	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$5x10^{-6}$
		I	$4x10^{-11}$	$9x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
Polonium (84)	Po 210	S	$5x10^{-10}$	$2x10^{-5}$	$2x10^{-11}$	$7x10^{-7}$
		I	$2x10^{-10}$	$8x10^{-4}$	$7x10^{-12}$	$3x10^{-5}$
Potassium (19)	K 42	S	$2x10^{-6}$	$9x10^{-3}$	$7x10^{-8}$	$3x10^{-4}$
		I	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
Praseodymium (59)	Pr 142	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (µc/ml)	Table I Column 2 Water (µc/ml)	Table II Column I Air (µc/ml)	Table II Column 2 Water (µc/ml)
	Pr 143	S	$3x10^{-7}$	$1x10^{-3}$	$1x10^{-8}$	$5x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$5x10^{-5}$
Promethium (61)	Pm 147	S	$6x10^{-8}$	$6x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
		I	$1x10^{-7}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Pm 149	S	$3x10^{-7}$	$1x10^{-3}$	$1x10^{-8}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
Protoactinium (91)	Pa 230	S	$2x10^{-9}$	$7x10^{-3}$	$6x10^{-11}$	$2x10^{-4}$
		I	$8x10^{-10}$	$7x10^{-3}$	$3x10^{-11}$	$2x10^{-4}$
	Pa 231	S	$1x10^{-12}$	$3x10^{-5}$	$4x10^{-14}$	$9x10^{-7}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$2x10^{-5}$
	Pa 233	S	$6x10^{-7}$	$4x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$2x10^{-7}$	$3x10^{-3}$	$6x10^{-9}$	$1x10^{-4}$
Radium (88)	Ra 223	S	$2x10^{-9}$	$2x10^{-5}$	$6x10^{-11}$	$7x10^{-7}$
		I	$2x10^{-10}$	$1x10^{-4}$	$8x10^{-12}$	$4x10^{-6}$
	Ra 224	S	$5x10^{-9}$	$7x10^{-5}$	$2x10^{-10}$	$2x10^{-6}$
		I	$7x10^{-10}$	$2x10^{-4}$	$2x10^{-11}$	$5x10^{-6}$
	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	$3x10^{-7}$	....	$3x10^{-8}$	....
	Rn 222		$1x10^{-7}$	....	$3x10^{-9}$	....
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	$7x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
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	$1x10^{-6}$	$6x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
Silver (47)	Ag 105	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$8x10^{-8}$	$3x10^{-3}$	$3x10^{-9}$	$1x10^{-4}$
	Ag 110m	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-8}$	$9x10^{-4}$	$3x10^{-10}$	$3x10^{-5}$
	Ag 111	S	$3x10^{-7}$	$1x10^{-3}$	$1x10^{-8}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
Sodium (11)	Na 22	S	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
		I	$9x10^{-9}$	$9x10^{-4}$	$3x10^{-10}$	$3x10^{-5}$
	Na 24	S	$1x10^{-6}$	$6x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
Strontium (38)	Sr 85m	S	$4x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$7x10^{-3}$
		I	$3x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$7x10^{-3}$
	Sr 85	S	$2x10^{-7}$	$3x10^{-3}$	$8x10^{-9}$	$1x10^{-4}$
		I	$1x10^{-7}$	$5x10^{-3}$	$4x10^{-9}$	$2x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (µc/ml)	Table I Column 2 Water (µc/ml)	Table II Column 1 Air (µc/ml)	Table II Column 2 Water (µc/ml)
	Sr 89	S	$3x10^{-8}$	$3x10^{-4}$	$3x10^{-10}$	$3x10^{-6}$
		I	$4x10^{-8}$	$8x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
	Sr 90	S	$3x10^{-10}$	$1x10^{-5}$	$3x10^{-11}$	$3x10^{-7}$
		I	$5x10^{-9}$	$1x10^{-3}$	$2x10^{-10}$	$4x10^{-5}$
	SR 91	S	$4x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$1x10^{-3}$	$9x10^{-9}$	$5x10^{-5}$
	SR 92	S	$4x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
Sulfur (16)	S 35	S	$3x10^{-7}$	$2x10^{-3}$	$9x10^{-9}$	$6x10^{-5}$
		I	$3x10^{-7}$	$8x10^{-3}$	$9x10^{-9}$	$3x10^{-4}$
Tantalum (73)	Ta 182	S	$4x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-8}$	$1x10^{-3}$	$7x10^{-10}$	$4x10^{-5}$
Technetium (43)	Tc 96m	S	$8x10^{-5}$	$4x10^{-1}$	$3x10^{-6}$	$1x10^{-3}$
		I	$3x10^{-5}$	$3x10^{-1}$	$1x10^{-6}$	$1x10^{-2}$
	Tc 96	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$5x10^{-5}$
	Tc 97m	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-7}$	$5x10^{-3}$	$5x10^{-9}$	$2x10^{-4}$
	Tc 97	S	$1x10^{-5}$	$5x10^{-2}$	$4x10^{-7}$	$2x10^{-3}$
		I	$3x10^{-7}$	$2x10^{-2}$	$1x10^{-8}$	$8x10^{-4}$
	Tc 99m	S	$4x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$6x10^{-3}$
		I	$1x10^{-5}$	$8x10^{-2}$	$5x10^{-7}$	$3x10^{-3}$
	Tc 99	S	$2x10^{-6}$	$1x10^{-2}$	$7x10^{-8}$	$3x10^{-4}$
		I	$6x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
Tellurium (52)	Te 125m	S	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$5x10^{-5}$
	Te 127	S	$2x10^{-6}$	$8x10^{-3}$	$6x10^{-8}$	$3x10^{-4}$
		I	$9x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	Te 129m	S	$8x10^{-8}$	$1x10^{-3}$	$3x10^{-9}$	$3x10^{-5}$
		I	$3x10^{-8}$	$6x10^{-4}$	$1x10^{-9}$	$2x10^{-5}$
	Te 129	S	$5x10^{-6}$	$2x10^{-2}$	$2x10^{-7}$	$8x10^{-4}$
		I	$4x10^{-6}$	$2x10^{-2}$	$1x10^{-7}$	$8x10^{-4}$
	Te 131m	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
	Te 132	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Terbium (65)	Tb 160	S	$1x10^{-7}$	$1x10^{-3}$	$3x10^{-9}$	$4x10^{-5}$
		I	$3x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$4x10^{-5}$
Thallium (81)	Tl 200	S	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$4x10^{-4}$
		I	$1x10^{-6}$	$7x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
	Tl 201	S	$2x10^{-6}$	$9x10^{-3}$	$7x10^{-8}$	$3x10^{-4}$
		I	$9x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	Tl 202	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$2x10^{-7}$	$2x10^{-3}$	$8x10^{-9}$	$7x10^{-5}$
	Tl 204	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$3x10^{-8}$	$2x10^{-3}$	$9x10^{-10}$	$6x10^{-5}$
Thorium (90)	Th 228	S	$9x10^{-12}$	$2x10^{-4}$	$3x10^{-13}$	$7x10^{-6}$
		I	$6x10^{-12}$	$4x10^{-4}$	$2x10^{-13}$	10^{-5}
	Th 230	S	$2x10^{-12}$	$5x10^{-5}$	$8x10^{-14}$	$2x10^{-6}$
		I	10^{-11}	$9x10^{-4}$	$3x10^{-13}$	$3x10^{-5}$
	Th 232	S	$3x10^{-11}$	$5x10^{-5}$	10^{-12}	$2x10^{-6}$
		I	$3x10^{-11}$	10^{-3}	10^{-12}	$4x10^{-5}$
	Th natural	S	$3x10^{-11}$	$6x10^{-5}$	10^{-12}	10^{-6}
		I	$3x10^{-11}$	$6x10^{-4}$	10^{-12}	10^{-5}
	Th 234	S	$6x10^{-8}$	$5x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
		I	$3x10^{-8}$	$5x10^{-4}$	10^{-9}	$3x10^{-5}$
Thulium (69)	Tm 170	S	$4x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$5x10^{-5}$
		I	$3x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$5x10^{-5}$
	Tm 171	S	$1x10^{-7}$	$1x10^{-2}$	$4x10^{-9}$	$5x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-2}$	$8x10^{-9}$	$5x10^{-4}$
Tin (50)	Sn 113	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$9x10^{-5}$
		I	$5x10^{-8}$	$2x10^{-3}$	$2x10^{-9}$	$8x10^{-5}$
	Sn 125	S	$1x10^{-7}$	$5x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$8x10^{-8}$	$5x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
Tungsten (Wolfram) (74)	W 181	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$1x10^{-7}$	$1x10^{-2}$	$4x10^{-9}$	$3x10^{-4}$
	W 185	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$1x10^{-7}$	$3x10^{-3}$	$4x10^{-9}$	$1x10^{-4}$
	W 187	S	$4x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
Uranium (92)	U 230	S	$3x10^{-10}$	$1x10^{-4}$	$1x10^{-11}$	$5x10^{-6}$
		I	$1x10^{-10}$	$1x10^{-4}$	$4x10^{-12}$	$5x10^{-6}$
	U 232	S	$1x10^{-10}$	$8x10^{-4}$	$3x10^{-12}$	$3x10^{-5}$
		I	$3x10^{-11}$	$8x10^{-4}$	$9x10^{-3}$	$3x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
	U 233	S	$5x10^{-10}$	$9x10^{-4}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$9x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	U 234	S	$6x10^{-10}$	$9x10^{-4}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$9x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	U 235	S	$5x10^{-10}$	$8x10^{-4}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	U 236	S	$6x10^{-10}$	$1x10^{-3}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$1x10^{-3}$	$4x10^{-12}$	$3x10^{-5}$
	U 238	S	$7x10^{-11}$	$1x10^{-3}$	$3x10^{-12}$	$4x10^{-5}$
		I	$1x10^{-10}$	$1x10^{-3}$	$5x10^{-12}$	$4x10^{-5}$
	U-natural	S	$7x10^{-10}$	$1x10^{-3}$	$3x10^{-12}$	$2x10^{-5}$
		I	$6x10^{-10}$	$1x10^{-3}$	$2x10^{-12}$	$3x10^{-5}$
Vanadium (23)	V 48	S	$2x10^{-7}$	$9x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$6x10^{-8}$	$8x10^{-4}$	$2x10^{-9}$	$3x10^{-5}$
Xenon (54)	Xe 131m	Sub	$2x10^{-5}$	....	$4x10^{-7}$	....
	Xe 133	Sub	$1x10^{-5}$	....	$3x10^{-7}$	....
	Xe 135	Sub	$4x10^{-6}$	....	$1x10^{-7}$	....
Ytterbium (70)	Yb 175	S	$7x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Yttrium (39)	Y 90	S	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$6x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
	Y 91m	S	$2x10^{-5}$	$1x10^{-1}$	$8x10^{-7}$	$3x10^{-3}$
		I	$2x10^{-5}$	$1x10^{-1}$	$6x10^{-7}$	$3x10^{-3}$
	Y 91	S	$4x10^{-8}$	$8x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
		I	$3x10^{-8}$	$8x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
	Y 92	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	Y 93	S	$2x10^{-7}$	$8x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-4}$
Zinc (30)	Zn 65	S	$1x10^{-7}$	$3x10^{-3}$	$4x10^{-9}$	$1x10^{-4}$
		I	$6x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
	Zn 69m	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	Zn 69	S	$7x10^{-6}$	$5x10^{-2}$	$2x10^{-7}$	$2x10^{-3}$
		I	$9x10^{-6}$	$5x10^{-2}$	$3x10^{-7}$	$2x10^{-3}$
Zirconium (40)	Zr 93	S	$1x10^{-7}$	$2x10^{-2}$	$4x10^{-9}$	$8x10^{-4}$
		I	$3x10^{-7}$	$2x10^{-2}$	$1x10^{-8}$	$8x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

c. Element (atomic number)	Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
If it is known that Sr 90, I 129, Pb 210, Po 210, At 211, Ra 23, 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 . . .	....	$6x10^{-5}$	....	$2x10^{-6}$
It it is known that Sr 90, Pb 210, Ra 226, Ra 228, are not present	....	$2x10^{-5}$	....	$6x10^{-7}$
It it is known Ra 226 and Ra 228, are not present	....	$3x10^{-6}$	....	$1x10^{-7}$
It 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	$3x10^{-9}$	....	$1x10^{-10}$	....
It it is known that alpha-emitters and Pb 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 1, Col. 1-1 x 10^{-10} μc/ml gross alpha activity; or 2.5 x $^{-11}$ μc/ml natural uranium; or 75 micrograms per cubic meter or air natural uranium.

b. For purposes of Table II, Col. 1-3 x 10^{-11} μc/ml gross alpha activity; or 8 x 10^{-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.

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.

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

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I		Table II	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
	Zr 95	S	$1x10^{-7}$	$2x10^{-3}$	$4x10^{-9}$	$6x10^{-5}$
		I	$3x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$6x10^{-5}$
	Zr 97	S	$1x10^{-7}$	$5x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$9x10^{-8}$	$5x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$

[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, end MPC_B and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

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

2. If either the identity of the concentration of any radionuclide in the mixture is not know, 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

APPEXDIX E

SC-M-68-227

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

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April 1968

ABSTRACT

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

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L E G A L N O T I C E

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TABLE OF CONTENTS

GENERAL TUNNEL REENTRY PROCEDURES FOR

DEPARTMENT OF DEFENSE AND SANDIA LABORATORY NUCLEAR TESTS

1. <u>Introduction</u>

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. <u>Responsibilities</u>

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 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 he 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. <u>Reentry Ground Rules</u>

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).

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

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.

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 he 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 he made within the limitations of this procedure.

i. Reentry will not he made beyond ventilation, 10 R/hr, 1000 ppm CO, or 10 percent of the lower explosive limit of explosive gas mixtures. Teams 1, 2, 3, and 4 may he 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. <u>Summary of Preshot Preparations for Reentry</u>

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

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

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

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

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

(1) Tunnel utilities and instrumentation. Power to these items will be turned off near zero time.
(2) Geophone transmitter trailer. This supplies power to the geophone and the pressure and temperature amplifiers which must be left on to monitor for cavity collapse and pressure changes.
(3) Ventilation fans. Power will be controlled remotely.
(4) Radiation detectors.
(5) Explosimeters.
(6) Ventilation and gas sampling valves. Power, will be controlled remotely.

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

g. Ventilation.

(1) The ventilation system is installed so that all areas of the tunnel that are not closed off are swept with fresh air from the portal.
(2) After zero time and when the TGD gives his approval (with the consent of the Test Manager), the tunnel ventilation system will be turned on, exhaust and makeup air will be supplied from the portal through valves in the gas seal door and, if possible, the overburden plug. There will be valves that can be remotely operated in both vent lines at the gas seal door and, if possible, at the overburden plug. Vent line samples will be taken to monitor for radioactive, explosive, and/or toxic effluents.

6. <u>Communications</u>

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

7. <u>Reentry Parties and Equipment</u>

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 REECo. 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) REECo 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	Necessary medical equipment.
M.D. and medical technician	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 I 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 he 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 4800 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.

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