



Draft Environmental Impact Statement

August 1992

Public Reading Room
U. S. Department of Energy
Idaho Operations Office

Space Nuclear Thermal Propulsion Program

Particle Bed Reactor Propulsion
Technology Development and Validation



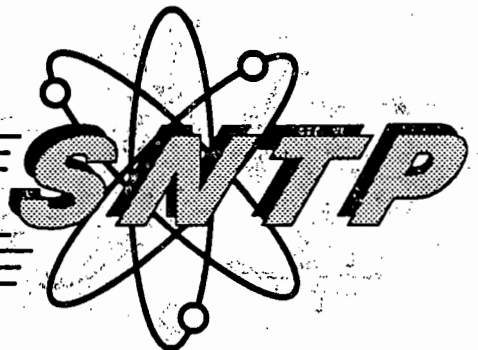
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DEPARTMENT OF THE AIR FORCE
WASHINGTON DC 20330-1000

OFFICE OF THE ASSISTANT SECRETARY

TO: ALL INTERESTED GOVERNMENT AGENCIES, PUBLIC GROUPS, AND
INDIVIDUALS

I am pleased to provide you with a copy of the Draft Environmental Impact Statement (DEIS) for the Space Nuclear Thermal Propulsion (SNTTP) program. The DEIS addresses potential environmental impacts of the proposed action to conduct validation testing of particle bed reactor technology. The document is provided in compliance with the National Environmental Policy Act as implemented by the Regulations of the President's Council on Environmental Quality.

There will be a 45-day review period for the DEIS ending October 5, 1992. Hearings will be held to provide individuals and organizations an opportunity to comment on the DEIS. The public hearing schedule is provided on the reverse.

If attendance is not possible, comments may be forwarded by mail to:

Capt Scott Hartford
AFCEE/ESEP
Building 1155
Brooks AFB, TX 78235-5000
(512) 536-3806

A handwritten signature in black ink, appearing to read "G. Vest", is written over the printed name "GARY D. VEST".

GARY D. VEST
Deputy Assistant Secretary of the Air Force
(Environment, Safety and Occupational Health)

1 Attachment
DEIS

**Schedule for Public Hearings on the Draft EIS for the
Space Nuclear Thermal Propulsion Program**

Date/Time

Location

**September 8, 1992
7:00 p.m.**

**Desert Inn
3145 Las Vegas Blvd. South
Las Vegas, NV 89109**

**September 10, 1992
7:00 p.m.**

**Holiday Inn
850 South Bluff Street
St. George, UT 84770**

**September 15, 1992
7:00 p.m.**

**Clarion Hotel
999 South Main
Salt Lake City, UT 84111**

**September 17, 1992
7:00 p.m.**

**Shilo Inn
780 Lindsay Blvd.
Idaho Falls, ID 83402**

DRAFT

ENVIRONMENTAL IMPACT STATEMENT

**SPACE NUCLEAR THERMAL
PROPULSION PROGRAM**

**Particle Bed Reactor Propulsion
Technology Development and Validation**

AUGUST 1992

COVER SHEET

DRAFT ENVIRONMENTAL IMPACT STATEMENT SPACE NUCLEAR THERMAL PROPULSION PROGRAM

- a. Responsible Agency: U.S. Air Force
- b. Cooperating Agency: Department of Energy
- c. Proposed Action: Technology development through validation testing of a particle bed reactor (PBR) propulsion system.
- d. Written comments and inquiries on this document should be received by October 5, 1992 and directed to: Capt. Scott Hartford, AFCEE/ESEP, Bldg. 1155, Brooks AFB, TX 78235-5000.
- e. Designation: Draft Environmental Impact Statement (DEIS)
- f. Abstract: The PBR concept has been under study in the United States since the early 1980s. During the past decade the PBR technology has advanced to the degree that the Air Force, in carrying out its mission to investigate promising technologies for military applications, proposes to conduct validation testing of the PBR technology for space propulsion as part of its Space Nuclear Thermal Propulsion (SNTTP) program. This EIS has been prepared in accordance with the National Environmental Policy Act to analyze the potential environmental consequences of the proposed construction and testing activities. The document analyzes the potential environmental impacts at each candidate test location, as well as the impacts of the No-Action Alternative. The analyses include infrastructure, land use, transportation, hazardous materials and hazardous waste management, biological resources, cultural resources, geology and soils, noise, water resources, and health and safety. Anticipated issues related to health and safety will be addressed in facility designs and safety procedures so that applicable statutes, regulations, and permits are met or exceeded. No impacts that exceed applicable limits have been identified at either candidate test location.



Summary

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SUMMARY

PURPOSE OF AND NEED FOR ACTION

This environmental impact statement (EIS) analyzes the potential environmental consequences of implementing a proposal to perform testing associated with the Space Nuclear Thermal Propulsion (SNTTP) program. The SNTTP program is an activity to pursue development of nuclear reactor technologies that have potential application to advanced space propulsion systems. In support of its mission, the Air Force has a continuing need to investigate new and promising technologies. The Air Force has tasked the Space and Missiles Technology Directorate of the Phillips Laboratory with the responsibility for validating and using advanced technologies to acquire and maintain superior space propulsion systems. Based on its technical merits, a nuclear technology known as a particle bed reactor (PBR) has been identified for validation as an advanced upper stage propulsion system.

The Air Force must comply with provisions of the National Environmental Policy Act (NEPA), which require preparation of an EIS. This study provides information to the decision makers and the public on the potential environmental impacts that could result from proceeding with development of the PBR propulsion technology through validation testing. The Department of Energy (DOE) is a cooperating agency in the preparation of this EIS and will participate with the Air Force in making decisions regarding the technology validation.

ALTERNATIVES INCLUDING THE PROPOSED ACTION

The Air Force proposes to develop the technology and demonstrate the feasibility of a PBR propulsion system that could be used to power an advanced upper stage rocket engine. The Proposed Action for this technology development program consists of development and testing of the engine and propellant management system components and assemblies, and construction and operation of validation testing facilities.

The PBR propulsion system would include a nuclear reactor consisting of an arrangement of fuel elements containing uranium-235 fuel particles, each covered with multiple layers of coating to provide containment of radioactive fission products. Cryogenic hydrogen would flow through the reactor and be heated as a result of cooling the fuel. The heated hydrogen would be expanded through the nozzle assembly, producing thrust.

A series of tests would be performed, leading to the validation of the concept. Tests would be sequenced to begin with testing of multiple assemblies to demonstrate reactor fuel element operation, progress through tests to demonstrate the propellant management system and culminate in

testing a series of up to ten reactors that gradually approach the desired performance conditions. Each test sequence would undergo a comprehensive safety analysis in accordance with DOE procedures for preliminary and final Safety Analysis Reports. Testing would be conducted in strict compliance with all applicable safety and environmental regulations and standards.

Two alternative PBR validation test sites are being considered as part of the Proposed Action:

- Construction and operation of the PBR validation test facilities at the Saddle Mountain Test Station (SMTS) at the Nevada Test Site (NTS) is being considered. The NTS is a DOE installation located in southern Nevada. Development of the facilities would involve construction on approximately 100 acres at SMTS. Infrastructure improvements such as road improvements and water and electric power service extensions would be required.
- Renovation of existing facilities and construction of some new facilities at the Contained Test Facility (CTF) at the Idaho National Engineering Laboratory (INEL) is being considered. The INEL is a DOE installation located in east-central Idaho. Development of the PBR validation test facilities would involve the renovation of existing facilities on approximately 55 acres of developed land plus additional acreage for construction of the remaining needed facilities. The total developed area would be approximately 100 acres.

The only alternative to the Proposed Action being considered is the No-Action Alternative. The No-Action Alternative would result in not carrying out the development and validation process for the PBR propulsion technology. Development of testing facilities would not occur under this alternative.

SCOPE OF STUDY

The scoping period began when the Notice of Intent to prepare an EIS for the SNTP program was published in the *Federal Register* on March 13, 1992. Issues related to the SNTP program were identified in scoping meetings held in Las Vegas, Nevada (April 7, 1992); Idaho Falls, Idaho (April 9, 1992); St. George, Utah (April 16, 1992); and Salt Lake City, Utah (April 22, 1992). The comments and concerns expressed at the scoping meetings and received during the public comment period were used in determining the scope and direction of studies and analyses required to accomplish this EIS.

This EIS discusses the potential environmental impacts associated with implementation of the Proposed Action and its siting alternatives. To provide the context in which potential environmental impacts may occur at

the two candidate field test locations and the surrounding communities, existing conditions and potential changes as a result of construction and test activities are described. Impacts to the physical and natural environment are evaluated for infrastructure, land use, transportation, hazardous materials/waste management, air quality, biological resources, cultural resources, geology and soils, noise, water resources, and health and safety.

SUMMARY OF ENVIRONMENTAL IMPACTS

This EIS considers the environmental impacts of proceeding with PBR technology development and validation and whether to perform the testing operations at SMTS or CTF. For purposes of summarizing and comparing environmental impacts, the alternatives are arranged as follows: proceeding with the Proposed Action at SMTS, proceeding with the Proposed Action at CTF, and the No-Action Alternative.

Influencing factors include projections based on program requirements that would likely influence the biophysical environment, including ground disturbance, socioeconomic factors, and infrastructure demands, as well as environmental (biophysical) impacts of the alternatives. Influencing factors and environmental impacts are summarized below and in Table S-1.

IMPLEMENTING THE PROPOSED ACTION AT SMTS

Community Setting/Influencing Factors

The community region of influence for the SMTS includes Nye and Clark counties, Nevada, including the city of Las Vegas. The program would require a maximum of 100 personnel during the peak construction period. Even if it is assumed that all such personnel would move into the area from outside the region of influence, there would be a negligible effect on population, local economy, and support service availability.

A new power line within the NTS power grid would be required; however, there is sufficient power at NTS to support this line. Solid waste, water supply, and wastewater consumption would represent a small increase in the total requirements, given existing capacities and past consumption levels.

No land use conflicts are anticipated as a result of implementing the Proposed Action at SMTS. The testing activities would be consistent with the type of research conducted at NTS.

Traffic due to the Proposed Action being implemented at SMTS would result in a small increase on the main route connecting NTS to Las Vegas (U.S. 95). No adverse effects are expected.

Table S-1. Summary of Impacts from Alternatives

	SMTS	CTF	No-Action
Local Community			
Land Use	No impact	No impact	No impact
Population	263; less than 0.04% increase	263; less than 0.2% increase	No impact
Employment	100 personnel; 2% increase	100 personnel; less than 1% increase	No impact
Transportation	Maximum of 5.9% increase in AADT	Maximum of 6.1% increase in AADT	No impact
Utilities			
Water	Less than 0.5% increase in withdrawal	Less than 0.1% of allocation	No impact
Electrical	New distribution line to the site required; 0.75 MW peak power requirement	Less than 1% of existing capacity required	No impact
Wastewater	2,400 gal/day; septic system/leachfield to be constructed	2,400 gal/day; less than 1% of existing capacity to be used	No impact
Solid Waste	Less than 1% increase	Existing and proposed new landfill sites contain sufficient capacity for solid wastes	No impact
Hazardous Materials/Waste			
Materials	Shipment of less than 220 pounds of U-235 per year (as part of component assemblies)	Shipment of less than 220 pounds of U-235 per year (as part of component assemblies)	No impact
Waste	Less than 2% increase per year	Less than 1% increase per year	No impact
CERCLA	No impact	No impact	No impact
Radioactive Materials	Approximately 18% of existing capacity for storage of low-level solid waste required	Approximately 46% of existing capacity for storage of low-level solid waste required	No impact
Natural Environment			
Air Quality	Slight increases in PM ₁₀ emissions and emissions from construction and worker vehicles. No impact on air basin attainment.	Slight increases in PM ₁₀ emissions and emissions from construction and worker vehicles. No impact on air basin attainment.	No impact
Biological Resources	Up to 1,000 Joshua trees impacted by construction; temporary impacts to wildlife during operations due to noise; no impact to sensitive habitats or threatened and endangered species; loss of 100 acres of vegetation; possible loss of birds in flare stack	Temporary impacts to wildlife during operations due to noise; no impact to sensitive habitats or threatened and endangered species; loss of less than 50 acres of previously disturbed vegetation; possible loss of birds in flare stack.	No impact
Cultural Resources	No adverse impacts	No adverse impacts to potentially significant historic resources (CTF) if mitigation identified by consultation process is implemented.	No impact
Geology & Soils	26,000 cubic yards of cut, 37,000 cubic yards of fill; new construction required to meet standards for Seismic Zone IV	4,000 cubic yards of cut and 4,000 cubic yards of fill. New construction required to meet standards for Seismic Zone II.	No impact
Noise	Temporary impacts to wildlife during operations; 390 acres exposed to 60 dBA or greater	Temporary impacts to wildlife during operations; 390 acres exposed to 60 dBA or greater	No impact
Water Resources	No impact on water table or water quality	No impact on water table or water quality	No impact
Health and Safety*			
Maximum Yearly Release	0.14% of natural dose	0.31% of natural dose	No impact
Total Lifetime Dose	0.06% of natural dose	0.13% of natural dose	No impact
Maximum Case Accident	5.6% of natural dose**	6.8% of natural dose**	No impact

* Exposures are shown for a maximally exposed individual; average exposures would be much less.

** Assumes no evacuations and no mitigation measures.

Biophysical Environment

Transportation of hazardous materials (both radioactive and nonradioactive) would comply with all applicable regulations, and no impacts are expected. Storage and use of hazardous materials would be consistent with current operations at NTS.

Nonradioactive and radioactive hazardous wastes would be disposed of in existing disposal facilities. All such facilities have sufficient capacity to support the SNTP program.

Air quality impacts resulting from implementation of the Proposed Action at SMTS would include fugitive dust (PM_{10}) emissions and exhaust emissions from construction and operations (vehicles and generators). Control of PM_{10} would minimize any impacts; the use of diesel generators may require permits from the state. No air quality impacts are expected from PBR test exhausts or the flaring of hydrogen.

Implementing the Proposed Action at SMTS would result in the loss of up to approximately 100 acres of low quality vegetation. Approximately 1,000 Joshua trees would be removed as a result of facility construction and infrastructure improvement needs; this could be mitigated by relocating the trees for landscaping uses. Minimal wildlife impacts would be expected; noise from the flare stack would frighten some animals temporarily, and any birds flying into the hydrogen flare would be killed. The desert tortoise, a threatened species, has been observed in the area, although no impacts are expected as a result of program activities. No sensitive habitats would be affected.

No adverse impacts to archaeological, historical, Native American, or paleontological resources are expected if the Proposed Action is implemented at SMTS.

No adverse impacts to geology, topography, or soils are expected. Localized temporary soil erosion would occur during ground disturbing construction activities. Effects from seismic activity are not expected. Effects from potential ground motion induced by NTS underground testing would be mitigated by designing and building the facilities in conformance with Seismic Zone IV (greatest seismic risk zone) construction requirements.

No noise impacts to non-project personnel or sensitive receptors are expected. Project personnel would comply with Occupational Safety and Health Administration noise limits and preventive/protective measures. Local wildlife would experience occasional temporary startle/fright effects.

Water use associated with implementing the Proposed Action at SMTS would result in a slight increase in water withdrawal from the aquifer. No water quality or surface water impacts are expected from normal operations.

Health and Safety

Radiological hazards associated with normal and accidental reactor test operations and radioactive material transportation were evaluated. Analysis was performed using selected computer modeling codes, with input determined through selection of bounding case weather conditions, radioactive releases, and controls.

Three types of planned operations using two different sized reactor cores were identified. The smaller of these two reactors, the PBR Integral Element Test (PIPET), would constitute the first self-sustained power-producing test of multiple PBR element assemblies; whereas the larger of the two, the Ground Test Article (GTA), would involve testing a complete PBR core to gradually approach desired system performance conditions. Planned operations correspond to low-power and full-power testing of the PIPET core, beyond full-power testing of the smaller reactor, and both low- and full-power tests using the larger GTA. Potential radiological releases were analyzed for all planned operational scenarios.

Modeling was performed for the maximum case year (the largest numbers of operations expected in a single year) and the proposed test program lifetime. Results from the maximum-case year are less than 1 percent of the naturally occurring radiation dose in the NTS vicinity, and are well below both regulatory limits (U.S. Environmental Protection Agency [EPA] emission standards) and the SNTP program goal of no more than 20 percent of applicable regulatory limits. Potential impacts of the test program were found to be extremely low relative to statistically expected occurrences in the population of interest.

Accident situations were also evaluated and a complete analysis performed for the identified maximum impact case: a release of a significant fraction of a PIPET core fission product inventory during weather conditions corresponding to maximum credible impacts. Results of this analysis indicate that the total dose to the Maximum Exposed Individual would be well below accident-case siting guidelines. The total impact on cancer fatalities and newborn genetic defect rates due to a maximum-case accident would be extremely low relative to the statistically expected occurrences in the population of interest.

IMPLEMENTING THE PROPOSED ACTION AT THE CTF

Community Setting/Influencing Factors

The community region of influence for the CTF includes those portions of a six-county area (Bannock, Bingham, Bonneville, Butte, Jefferson, and Madison counties) within 50 miles, including Idaho Falls. The program would require a maximum of 100 construction personnel during the peak construction period. Negligible effects on population, local economy, and support service availability would result.

Electricity, solid waste, wastewater, and water supply consumption would represent only small increases in the total requirement, given existing capacities and past consumption levels. No land use conflicts are anticipated as a result of implementing the Proposed Action at CTF due to the nature of research activities at INEL.

Traffic due to implementing the Proposed Action would represent a small increase on roads accessing CTF (U.S. 33). Traffic on public roads traversing the INEL may have to be rerouted during and immediately after some test operations. No adverse effects are expected.

Biophysical Environment

Transportation of hazardous materials (both radioactive and non-radioactive) would comply with all applicable regulations, and no impacts are expected. Storage and use of hazardous materials would be consistent with current operations at INEL.

Non-radioactive and radioactive hazardous wastes would be disposed in existing disposal facilities. All such facilities would have sufficient capacity to support the SNTP program.

Air quality impacts that would occur from implementation of the Proposed Action at SMTS would include PM_{10} emissions and exhaust emissions from construction and operations (vehicles and generators). Control of PM_{10} would minimize any impacts. No air quality impacts are expected from PBR test exhausts or the flaring of hydrogen.

Implementing the Proposed Action at CTF would result in the loss of approximately 50 acres of previously disturbed, low quality vegetation. Minimal wildlife impacts would be expected due to the developed nature of the area. One endangered species (the bald eagle) has been observed in the area, although no impacts are expected as a result of program activities. No sensitive habitats would be affected.

The existing containment structure at CTF is potentially eligible for the National Register of Historic Places; possible adverse impacts are being mitigated through consultation with the State Historic Preservation Officer. No adverse impacts to archaeological, Native American, or paleontological resources are expected.

No adverse impacts to geology, topography, or soils are expected. The natural topography near the site may be subjected to flooding; however, the CTF elevation has been raised 15 feet in the past to keep the site from being flooded in the case of failure of upstream flood control structures. Localized temporary soil erosion would occur during ground disturbing construction activities. Effects from seismic and volcanic activity are not expected.

No noise impacts to non-project personnel or sensitive receptors are expected. Project personnel would comply with Occupational Safety and Health Administration noise limits and preventive/protective measures. Local wildlife would experience occasional temporary startle/fright effects.

Water use from implementing the Proposed Action at CTF would have negligible effects on drawdown in the aquifer. No water quality or surface water impacts are expected from normal operations.

Health and Safety

Radiological hazards associated with normal and accidental reactor test operations and radioactive material transportation were evaluated. Analysis was performed using selected computer modeling codes, with input determined through selection of bounding case weather conditions, radioactive releases, and controls.

Three types of planned operations using two different sized reactor cores were identified. The smaller of these two reactors, the PIPET, would constitute the first self-sustained power-producing test of multiple PBR element assemblies; whereas the larger of the two, the GTA, would involve testing a complete PBR core to gradually approach desired system performance conditions. Planned operations correspond to low-power and full-power testing of the PIPET core, beyond full-power testing of the smaller reactor, and both low- and full-power tests using the larger GTA. Potential radiological releases were analyzed for all planned operational scenarios.

Modeling was performed for the maximum-case year (the largest numbers of operations in a single year) and the proposed test program lifetime. Results from the maximum-case year are less than 1 percent of the naturally occurring background radiation dose in the INEL vicinity, and well below both regulatory limits (U.S. EPA emission standards) and the SNTP program goal of no more than 20 percent of applicable regulatory limits. Potential

impacts of the test program were found to be extremely low relative to statistically expected occurrences of cancer fatalities and newborn genetic defects in the population of interest.

Accident situations were also evaluated and a complete analysis performed for the identified maximum-impact case: a release of a significant fraction of a PIPET core fission product inventory during weather conditions corresponding to maximum credible impacts. Results of this analysis indicate that the total dose to the Maximum Exposed Individual would be well below accident-case allowable exposures. The total increase in cancer fatalities and newborn genetic defect rates due to a maximum-case accident would be extremely low relative to the statistically expected occurrences in the population of interest.

NO-ACTION ALTERNATIVE

Under the No-Action Alternative, the Air Force would not proceed with PBR technology development and validation. Other unrelated current activities at NTS and INEL would continue. No construction of new facilities would occur at SMTS, and no modification or construction of facilities would occur at the CTF.

Because none of these activities would take place, no impacts beyond those occurring as a result of other current programs or activities would result. No effects would occur in any of the influencing factors or biophysical resource areas.

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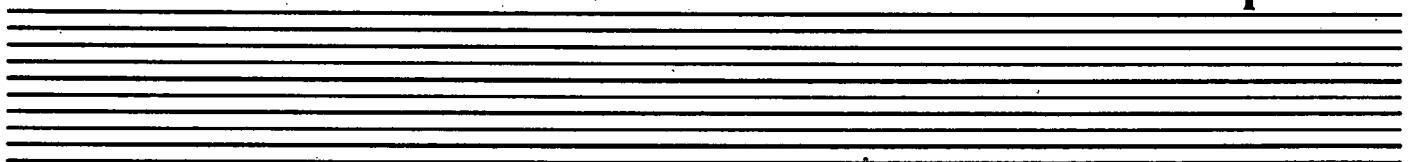
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Chapter 1



1.0 PURPOSE OF AND NEED FOR THE PROPOSED ACTION

This environmental impact statement (EIS) analyzes the potential environmental consequences of proceeding with a proposal to perform ground-based testing associated with the Space Nuclear Thermal Propulsion (SNTTP) program. The SNTTP program is an activity to pursue development of nuclear reactor technologies with potential application to advanced space propulsion systems. The program would develop and demonstrate the feasibility of high temperature nuclear thermal propulsion technologies. Upon successful completion of a developmental and feasibility effort, high temperature nuclear reactor propulsion systems could be applied to both future advanced upper stage rocket engines and orbital transfer vehicles.

The Air Force currently considers the Particle Bed Reactor (PBR) propulsion technology to have sufficient developmental potential to warrant continued investigation. This EIS evaluates the potential environmental impacts associated with the Proposed Action, which is to develop and validate PBR technology. This document has been prepared in accordance with the National Environmental Policy Act (NEPA) of 1969 and the Council on Environmental Quality (CEQ) regulations implementing the NEPA (40 Code of Federal Regulations [CFR] Parts 1500-1508).

Appendix A includes a glossary of terms used, a list of acronyms and abbreviations, and a separate list of the abbreviations used for elements/chemicals discussed.

1.1 BACKGROUND

In the early 1980s, scientists at Brookhaven National Laboratory, New York, developed the PBR concept. After years of refinement, this concept currently consists of a bed of very small, ceramic-coated particles containing nuclear material that are allowed to undergo a fission (atom splitting) reaction. The intense heat from the fission reaction is removed from the reactor by forcing a super-cooled gas through the reactor body and around the particles; in the process the gas becomes superheated.

Use of very small, ceramically coated spheres maximizes the surface area over which the gas can flow, resulting in very efficient transfer of heat from the fuel particles to the gas. This arrangement also maximizes the production of neutrons, which are both a product of the fission reaction and necessary to sustain it. These two factors - maximum particle surface area and high neutron production - produce a very high level of power output from a very small quantity of fuel; in other words, the PBR has a very high power density.

These features soon led to designs that exploited the high power density of the PBR. One of the most compelling of these applications is the PBR nuclear rocket engine. The PBR engine would be a new type of nuclear reactor that would use hydrogen as both a reactor coolant and a propellant. In doing this, the high power density of the PBR, in conjunction with the low molecular weight of the hydrogen, would allow both a high thrust-to-weight ratio and a high specific impulse (Isp) (which relates to the efficiency at which propellant is used to produce thrust). This concept enables a substantial number of missions not possible with either conventional propulsion systems or other nuclear rocket engine concepts, whose design and geometrical configurations limit either the Isp or thrust-to-weight ratio.

Recently, the government and industry have advanced the PBR technology for potential applications to space propulsion. In 1989 each Service Secretary attested to the breakthrough potential and utility of the concept (Atwood, 1989). Further, the concept has been reviewed by two independent Defense Science Boards (DSBs) (1990 DSB Task Force on Special Technology and 1989 DSB on National Launch Strategy). Both of these DSBs confirmed the need for development of advanced propulsion systems and endorsed the PBR propulsion technology development specifically. The DSB Task Force on Special Technology concluded, in part, that:

- The PBR propulsion technology is technically sound and could provide twice the performance (Isp) of conventional chemical propulsion.
- The PBR propulsion technology can be validated in conformance with all safety and environmental criteria.
- Potential national benefits could be obtained from follow-on applications in military, commercial/industrial, energy, and other space programs.
- Development of the PBR propulsion technology deserves broad support.

Other potential nuclear thermal reactor concepts with similar performance objectives have been proposed for advanced space propulsion. Detailed evaluation of these concepts by several governmental agencies, which included a second DSB evaluation in 1992, concluded that:

- The SNTP program is worthy of continued support to develop and validate PBR propulsion technology.
- PBR propulsion development and validation would provide a significant contribution to the knowledge and capability of future space exploration.

The Air Force, through the SNTP office, is leading and coordinating the technical, safety, environmental, and management activities of the Department of Defense, the Department of Energy (DOE), and the National Aeronautics and Space Administration. DOE would be responsible for the test site and associated test facilities and for the nuclear aspects of the program such as operations and testing, nuclear requirements, and nuclear safety.

1.2 NEED FOR THE ACTION

Several propulsion technologies, both conventional and nuclear, have been and continue to be considered as viable research options. However, PBR propulsion technology has been viewed by the Air Force as a concept with distinct advantages over conventional propulsion capabilities. Based on technical merit, the Air Force considers the PBR propulsion technology as the most noteworthy option for continued research and development on the basis of the following:

- High power density which would enable a high thrust-to-weight ratio
- High specific impulse (roughly two to three times that of conventional chemical systems)
- Broad mission applicability.

1.3 PURPOSE OF THE ACTION

The purpose of the action is twofold. First, in order to be a technologically superior force in the future, the Air Force has a continuing mission to investigate new and promising technologies that may have potential application to (1) increase global projection of power, (2) reduce the cost of military operations, and (3) reduce logistics aspects of maintaining its military force structure. Second, there is a corresponding mission to investigate specific concepts that can meet future Air Force needs. With regard to this, the Air Force has tasked the Space and Missiles Directorate of the Phillips Laboratory with the responsibility to validate and use advanced technologies to acquire and sustain superior systems capability in areas of space power and propulsion. The ultimate utility of these advanced technologies is also contingent on their technical viability, cost-effectiveness, and the overall safety strategy employed in their use.

Substantial conceptual and technical data exist to characterize the PBR technology; however, additional information is needed to support application of this technology to advanced propulsion systems. The purpose of the SNTP program would be to demonstrate the technical and economic feasibility and safety of the PBR technology in propulsion applications,

including continued research and development addressing necessary materials and other supporting technologies. The SNTP program office has focused its efforts on validation of the PBR technology for these applications and has established a requirements matrix generated from documented mission needs, calling for less expensive and more operationally effective access to space. This could be achieved by implementing the nuclear thermal propulsion system in an upper stage configuration. Validation of the technology would be accomplished through a series of ground based partial- and full-power tests to determine whether further system development and integration are warranted.

The proposed PBR validation test facility would be designed with as much flexibility as possible to accommodate the development and validation needs of future nuclear thermal propulsion technology programs. While further NEPA documentation may be required for future programs, the advantage of this design flexibility is in providing an established facility that could be cost-effectively modified to accommodate testing requirements.

1.4 DECISIONS TO BE MADE

As the lead agency, the Air Force is preparing this EIS to provide the decision makers and the public with the information required to understand the potential environmental consequences resulting from construction of a test facility and PBR development and validation testing. After completion of the EIS, a Record of Decision (ROD) will be issued relative to efforts associated with the SNTP program. The ROD will determine the following:

- Whether to continue the SNTP program through the development of nuclear thermal propulsion technology
- Whether to construct and operate a PBR validation test facility
- Where to locate the PBR validation test facility if the program is to continue.

This EIS is limited to the PBR propulsion technology development and validation portions of the SNTP program. Further testing will not be planned unless the PBR propulsion technology development and validation program is successful. Further NEPA documentation would be prepared prior to any decisions on additional test programs, should follow-on activities be pursued.

1.5 ENVIRONMENTAL IMPACT ANALYSIS PROCESS

The NEPA of 1969 established a national policy to protect the environment by requiring that federal agencies consider the environmental effects of actions in their decision-making. NEPA also established the CEQ to oversee

and recommend national policies to improve the quality of the environment. Subsequently, CEQ published regulations that described how NEPA should be implemented. The CEQ regulations encourage federal agencies to develop and implement procedures that address the NEPA process, in order to avoid or minimize adverse effects on the environment. Air Force Regulation (AFR) 19-2 addresses implementation of NEPA as part of the Air Force planning and decision-making process. Regulation 10 CFR Part 1021 implements NEPA for DOE decision making.

NEPA and AFR 19-2 provide guidance on the types of actions for which an EIS must be prepared. Once it has been determined that an EIS must be prepared, the proponent must publish a Notice of Intent (NOI) to prepare an EIS. This formal announcement signifies the beginning of the scoping period, during which the major environmental issues to be addressed in the EIS are identified. A Draft EIS (DEIS) is prepared, which includes the following:

- A statement of the purpose of and need for the action
- A Description of the Proposed Action and Alternatives, including the No-Action Alternative
- A description of the environment that would be affected by the action and alternatives
- A description of the potential environmental consequences of the action and alternatives.

The DEIS is filed with the Environmental Protection Agency (EPA), and is circulated to interested public and government agencies for a period of at least 45 days for review and comments. During this period, a public hearing may be held so that the proponent can summarize the findings of the analysis and receive input from the affected public. At the end of the review period, all substantive comments received must be addressed. A Final EIS (FEIS) is produced that contains responses to comments, as well as changes to the document, if necessary.

The FEIS is then filed with the EPA and distributed in the same manner as the DEIS. Once the FEIS has been available for at least 30 days, the ROD for the Action may be published.

The Proposed Action, including two alternative validation testing sites, and a No-Action Alternative have been identified for the SNTP program. The two sites are the Saddle Mountain Test Station (SMTS) at the Nevada Test Site (NTS) and the Contained Test Facility (CTF) (formerly known as the Loss-of-Fluid Test site) at the Idaho National Engineering Laboratory (INEL). The SMTS site would require new construction for all of the facilities; some

existing facilities would be modified and reused at CTF, while some new construction would be required. Although a site narrowing report (Appendix F) identified the SMTS as being a preferred site, the Air Force and DOE have determined that both proposed sites are to be considered equally.

The Air Force has prepared this EIS in cooperation with DOE. As a cooperating agency, DOE would host the validation test operations at one of the aforementioned DOE installation sites if the decision is to proceed with the Proposed Action.

Scoping Process.

To encourage public involvement in the decision making process, the Air Force began the scoping process by publishing an NOI to prepare an EIS in the *Federal Register* on March 13, 1992 (Appendix B). Notification of public scoping meetings was published in local newspapers and announced on local radio stations. Mailers were also sent to known interested parties.

The scoping period for this EIS began on March 13, 1992. Four public meetings were held during the scoping period to solicit comments and concerns from the general public: at Las Vegas, Nevada, on April 7, 1992; at Idaho Falls, Idaho, on April 9, 1992; at St. George, Utah, on April 16, 1992; and at Salt Lake City, Utah, on April 22, 1992. Representatives of the Air Force presented an overview of the meeting's objectives, agenda, and procedures, and described the process and purpose for the development of the SNTP program EIS.

In addition to verbal comments, many written comments were received during the scoping period. These comments, as well as information from previous Air Force experience with similar programs, and NEPA requirements, were used to determine the scope of analyses to accomplish this EIS. Copies of this EIS have been mailed to the organizations and individuals listed in Appendix C.

1.6 ORGANIZATION OF THE EIS

Chapter 1 of this EIS presents a brief history of the program, the need for and purpose of the action, information relating to the environmental impact analysis process, and a list of federal permits, licenses, and entitlements potentially required for SNTP technology development activities. Chapter 2 presents a description of the PBR propulsion system, the Proposed Action, the two siting alternatives, the No-Action Alternative, and a brief discussion of those alternatives evaluated early in the process but later eliminated from consideration. Chapter 3 describes the affected environment at the two alternative sites, including discussions on the regional environments of the NTS and the INEL. Chapter 4 assesses the potential environmental consequences of the Proposed Action at each alternative site and discusses

measures that would be taken to minimize impacts at affected installations. Agencies that were consulted while preparing this EIS are identified in Chapter 5, and the names of EIS authors and contributors and complete reference citations are in Chapters 6 and 7, respectively. Chapter 8 contains a topic index, and numerous appendices provide a variety of supporting data and documents.

1.7 RELATED ENVIRONMENTAL DOCUMENTS

The declassified EIS prepared for an advanced technology program was used, in part, in the preparation of this EIS. Copies may be obtained from the U.S. Department of Commerce, National Technical Information Service:

National Technical Information Service
Springfield, Virginia 22161
(703) 487-4600

Document No. AD/A 248408 (EIS)
Document No. AD/A 248409 (Addendum to the EIS)

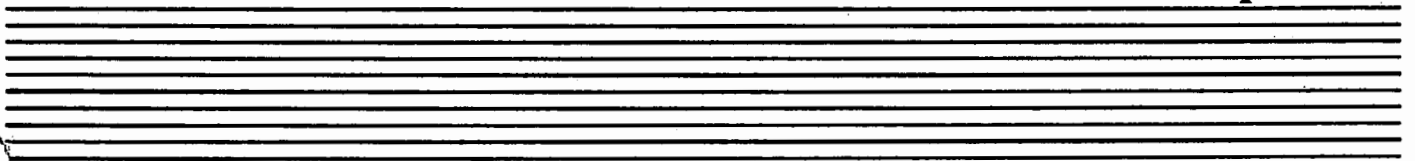
1.8 RELEVANT FEDERAL PERMITS, LICENSES, AND ENTITLEMENTS

Federal permits, licenses, and entitlements that may be required are presented in Table 1.8-1.

Table 1.8-1. Federal Permits, Licenses, and Entitlements Potentially Required for SNTP Technology Development Activities

Federal Permit, License, or Entitlement	Typical Activity, Facility, or Category of Persons Required to Obtain the Federal Permit, License, or Entitlement	Regulatory Agency	Authority
Title V permit under the Clean Air Act (CAA), as amended by the 1990 Clean Air Act Amendments	Any major source (source that emits more than 100 tons/year of criteria pollutant in nonattainment area for that pollutant or is otherwise defined in Title I of CAA as a major source); affected sources as defined in Title IV of CAA; sources subject to Section 111 regarding New Source Performance Standards; sources of air toxics regulated under Section 112 of CAA; sources required to have new source or modification permits under Parts C or D of Title I of CAA; and other sources designated by EPA regulations	U.S. Environmental Protection Agency (EPA); applicable state Air Pollution Control District if state has EPA-approved air quality control program	Title V of CAA
National Pollution Discharge Elimination System permit	Discharge of pollutant from any point source into waters of the United States	U.S. EPA; State Water Quality Control Board	Section 402 of Federal Water Pollution Act, 33 USC §1342
EPA manifest identification number	Generators or transporters (off-site transport) of hazardous waste	U.S. EPA	40 CFR Part 262.10 (generators); 40 CFR Part 263, Subpart B (transporters)
Antiquities permit	Excavation and/or removal of archaeological resources from public lands or Indian lands and carrying out activities associated with such excavation and/or removal	U.S. Dept. of the Interior, National Park Service	Archaeological Resource Protection Act of 1979, 16 USC §470cc
Endangered Species Act §10A permit	Taking endangered or threatened wildlife species; engaging in certain commercial trade of endangered or threatened plants or removing such plants on property subject to federal jurisdiction	U.S. Dept. of Interior, Fish & Wildlife Service	Section 10A of Endangered Species Act, 16 USC §1539; 50 CFR Part 17, Subparts C,D,F, & G

Chapter 2



2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

This chapter discusses the Proposed Action, two alternative sites for implementing the Proposed Action, and the No-Action Alternative. A conceptual Particle Bed Reactor (PBR) system is described in detail, as are the proposed test program, test facilities, and decontamination and decommissioning activities at the end of the program. Alternatives eliminated from further consideration are addressed, and a comparison of environmental impacts is provided in table form.

2.1 PROJECT OVERVIEW

The Air Force proposes to develop the technology and demonstrate the feasibility of a high-temperature PBR propulsion system that could be operated outside the atmosphere in space as an advanced upper stage nuclear rocket engine or an orbital transfer vehicle. A conceptual propulsion system is shown in Figure 2.1-1. The general concept of the nuclear propulsion system involves use of the PBR to heat cryogenic hydrogen propellant to very high temperature gaseous hydrogen. The hot hydrogen is exhausted through a nozzle to produce thrust.

The Proposed Action for this propulsion technology development and validation program consists principally of (1) development and validation of the PBR propulsion technology and (2) construction and operation of necessary testing facilities.

Major technological goals of the Space Nuclear Thermal Propulsion (SNTP) program include the achievement and control of predicted nuclear power levels; the development of materials that can withstand the extremely high operating temperatures and hydrogen flow environments; and the reliable control of cryogenic and high temperature hydrogen propellant.

2.2 DESCRIPTION OF PROPOSED ACTION

Three decisions are to be made regarding the program: (1) whether to continue the SNTP program through the development of nuclear thermal propulsion technology; (2) whether to construct and operate a PBR validation test facility; and (3) where to locate the PBR validation test facility if the program is to continue. Information related to each of these decisions is described in this chapter and is organized in the following manner:

- **Whether to continue with the technology.** The principal PBR subsystems are described and elements of the test program are detailed.

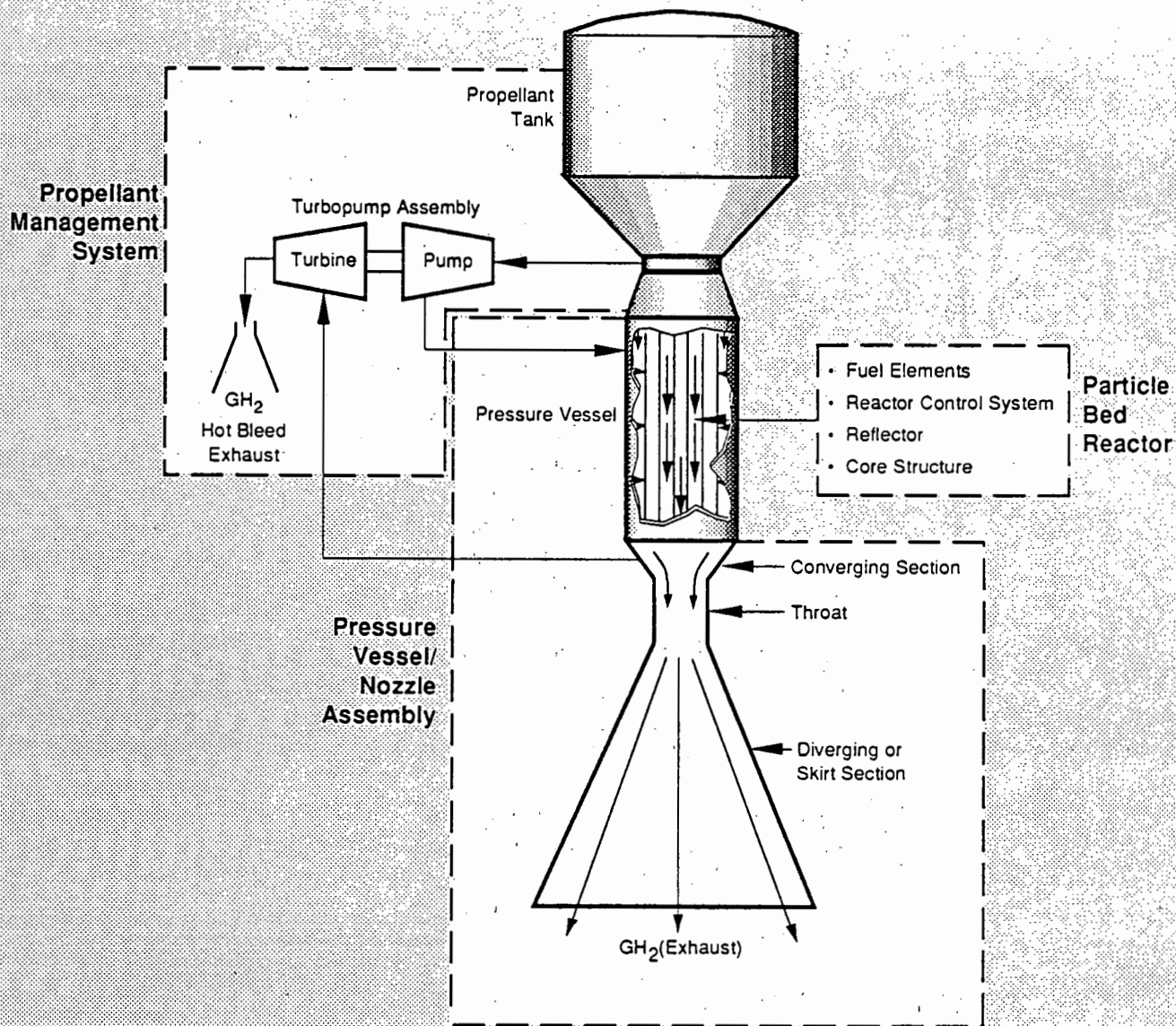


Diagram Not to Scale

**Conceptual PBR
Propulsion System**

Figure 2.1-1

- Whether to construct and operate a PBR validation test facility. The components of the sub-scale and full-scale test facilities are described in this section, and requirements typical for both construction and renovation for the facilities are detailed.
- Where to locate the PBR validation test facility. Sites at two Department of Energy (DOE) installations are described: the Saddle Mountain Test Station (SMTS) site at Nevada Test Site (NTS), which would require new construction; and the Contained Test Facility (CTF) site at Idaho National Engineering Laboratory (INEL), which would require renovation of existing facilities and new construction.

The principal technology issues and goals related to the propulsion technology are (1) verification of the PBR concept; (2) design and fabrication of high temperature fuel particles; (3) design and fabrication of the hot frits (concentric porous cylinders to contain the fuel particles) to withstand high temperatures and resist adverse reactions with the fuel particles or the flowing of coolant; (4) design of the cold frits to distribute coolant and match flow to power; (5) design and fabrication of the engine nozzle to withstand the high temperatures and to resist adverse reactions with the hydrogen gas; and (6) design of a reliable reactor control system.

2.2.1 PBR Propulsion System Description

This section describes a conceptual design of a nuclear thermal propulsion system, based on a PBR. The final PBR propulsion system design will evolve as development occurs. The following paragraphs provide a conceptual overview of the system and basic components for illustrative purposes.

Use of fuel-particle technology (see Section 2.2.1.1) in reactor design is not a new idea, and has been considered for commercial and breeder reactor applications both in the United States and abroad (Bairiot et al., 1970; Kania, 1990). A significant advantage in efficiency can be achieved by using a packed bed of fuel particles which, due to high surface area-to-volume ratio, supports operation at high power densities while maintaining fuel temperatures at acceptable levels. This high power density implies a high thrust-to-weight capability, which is preferable for Air Force operations in space. As a result, the PBR concept has received significant attention in the technical community as a means of improving performance in orbital transfer vehicles and deep-space propulsion systems (Powell and Botts, 1983; Ludewig, 1991).

The principal components of a conceptual PBR propulsion system are the particle bed reactor, the pressure vessel/nozzle assembly, and the propellant management system (see Figure 2.1-1). With the exception of the reactor, most of the major components are typical of any rocket engine

system and are not unique to PBR designs. Further discussion of the principal components is presented below.

2.2.1.1 Particle Bed Reactor. The PBR would use spherical fuel particles. A typical fuel element could contain many millions of these fuel particles, each approximately 0.5 millimeters in diameter. A typical particle (Figure 2.2-1) contains a kernel of fully enriched uranium-235 (U-235) surrounded by a porous graphite buffer layer. Next is a high-density graphite layer which is surrounded by a final layer of zirconium carbide. These multiple coatings provide containment of fission products and prevent the heated hydrogen from damaging kernel material. Other similar particle designs that may have high performance characteristics (e.g., higher temperature capability kernel or improved coating) are also possible.

Each hexagonal fuel element (see Figure 2.2-1) includes neutron moderator material, a set of concentric frits and the fuel particles. The concentric frits are devices that structurally support the fuel particles while allowing hydrogen to flow through the material and cool the fuel particles. Flow paths through an element are illustrated in Figure 2.2-1. The entire fuel element assembly would be surrounded by a neutron reflector such as graphite or beryllium to enhance reactor performance.

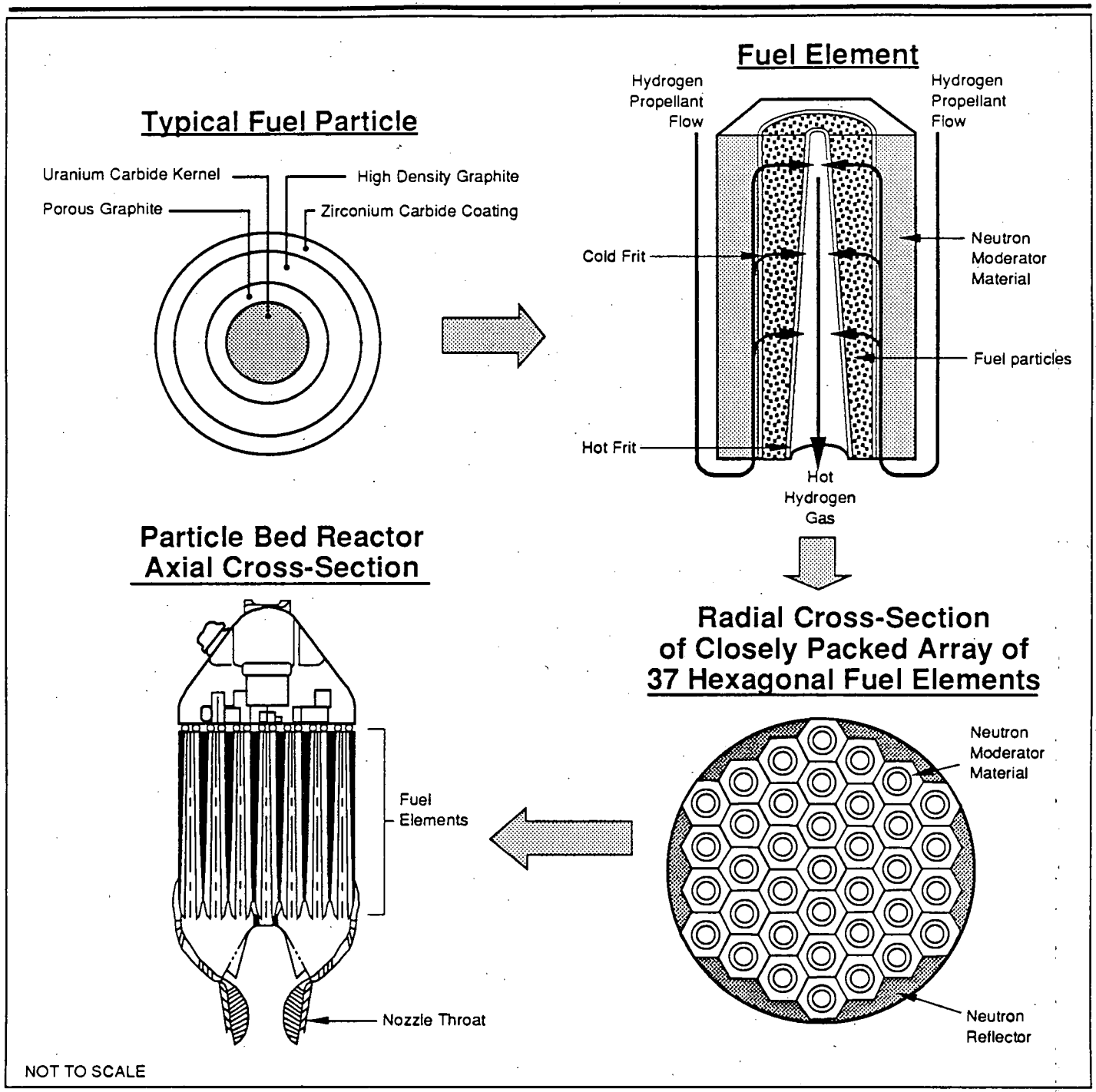
The PBR configuration under consideration consists of a closely packed array of hexagonal-shaped fuel elements, surrounded by neutron moderating and reflector materials and reactor control devices (safety rods and control drums) (Figure 2.2-2). Use of an array of hexagonal fuel elements allows the option of a modular design, where the number of elements used (e.g., 19, 37, or 61) would be tailored to produce the desired thrust.

Cryogenic hydrogen (35 to 50 Kelvin [K] or -238° to -223° Centigrade [C]) coolant flows into the reactor. As it cools the fuel, the hydrogen heats up and enters the nozzle assembly where it expands, producing thrust.

2.2.1.2 Pressure Vessel/Nozzle Assembly. The pressure vessel/nozzle assembly (see Figure 2.1-1) would perform the following two tasks:

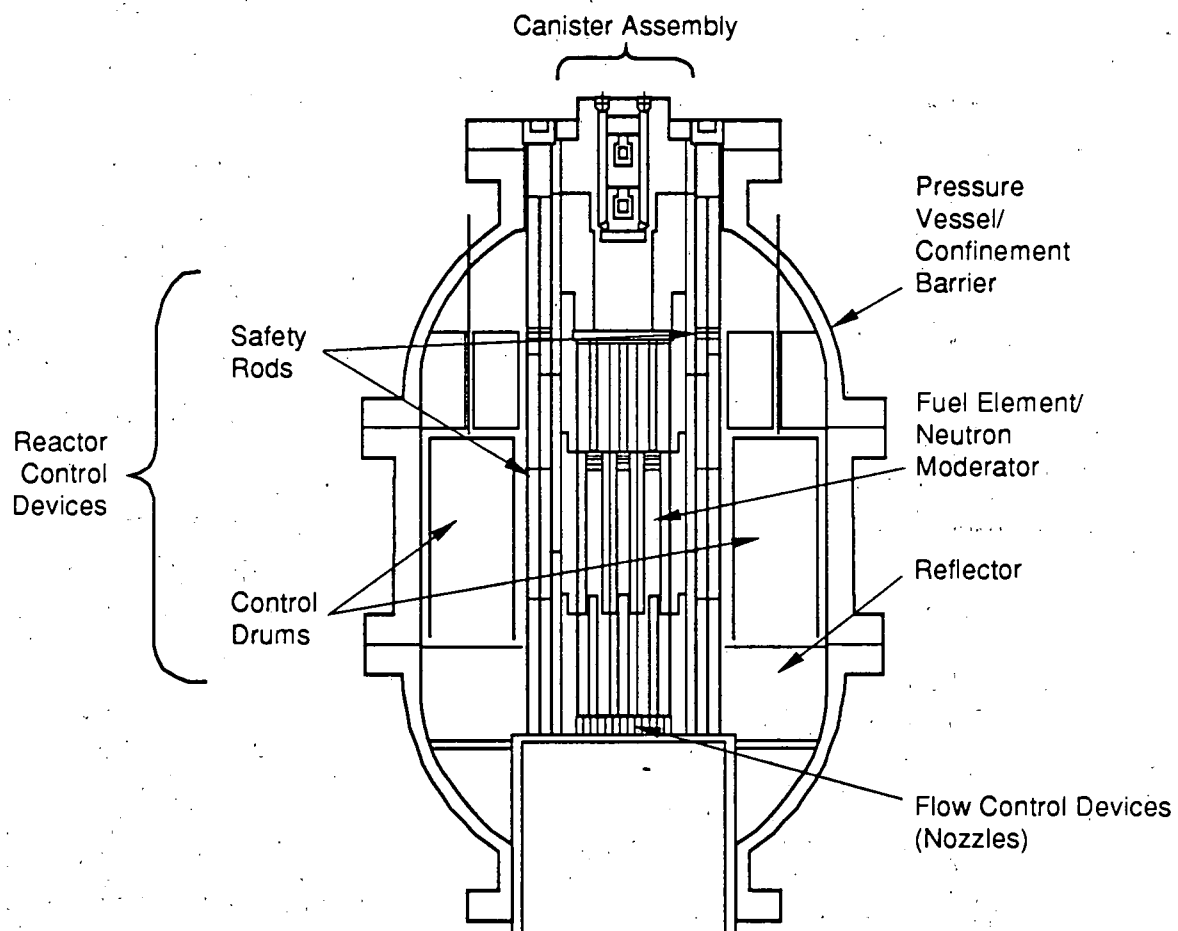
- Provide pressure containment and structural support for the PBR
- Collect hydrogen gas from each reactor fuel element and accelerate the gas through the throat section of the nozzle to generate thrust.

2.2.1.3 Propellant Management System. The purpose of the propellant management system (see Figure 2.1-1) is to provide controlled flow and pressure to the reactor and any ancillary subsystems. The system also contains provisions for tank pressurization and chilldown/conditioning of cryogenic fluid paths. During operation, cryogenic hydrogen exits the



Particle Bed Reactor Description

Figure 2.2-1



NOT TO SCALE

**PIPET Axial
Cross-Section**

Figure 2.2-2

propellant tank and enters the pump section of the turbopump assembly. After exiting the pump, the propellant is delivered to the reactor where it is heated to the desired temperature. A small portion of the propellant is bled off to power the turbopump assembly and the balance is subsequently expanded through the nozzle.

2.2.2 Test Program

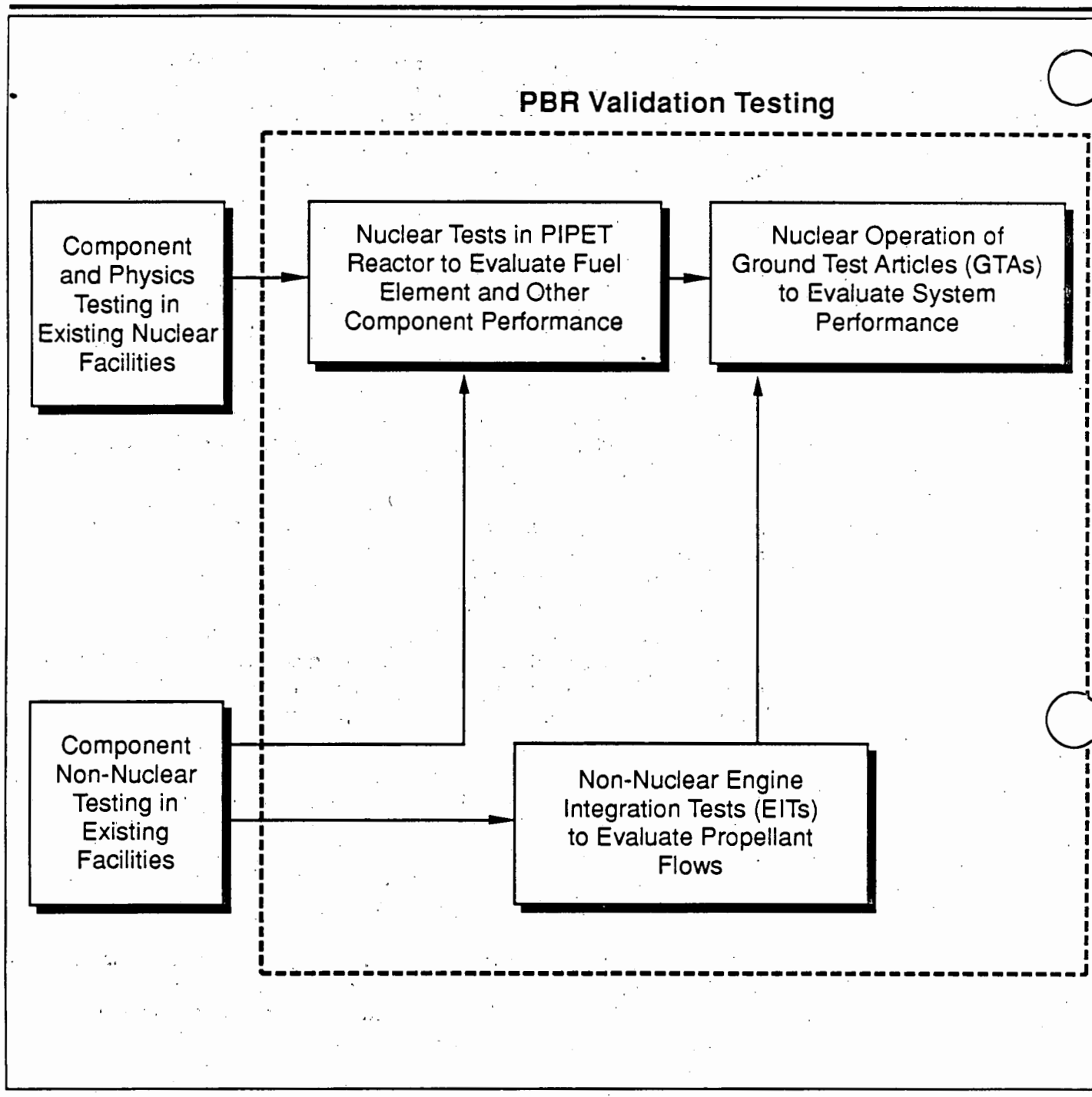
This section describes the validation testing of the PBR propulsion technology. The proposed testing would demonstrate the technology through a series of tests over a 5- to 10-year period leading to the validation of the PBR concept. As shown in Figure 2.2-3, the tests are sequenced to commence with fuel element testing and culminate in complete system testing. Specifically, this test series includes the PBR Integral Performance Element Tests (PIPET) and the Engine Integration Tests (EIT) as well as tests of Ground Test Articles (GTAs).

2.2.2.1 Planned Test Operation. Standard operating procedures would be prepared for each test. Each test series would be carefully planned to include written procedures and formal review and approval. Procedures would also be developed for material receipt and storage, preliminary assembly, post-irradiation component disassembly, inspection of major components, and associated transportation requirements. Development of operating procedures would be based upon preceding program results; supporting experimentation; validated analysis; and safety, environmental, and procedural requirements.

A Remote Inspection and Maintenance System would be provided to permit timely evaluation of the test reactors in a high-radiation environment. The capability of conducting multiple operations using the same reactor core assembly would depend on the ability of this system to verify the integrity of the fuel elements prior to commencing each reactor operation.

Each test sequence would undergo a comprehensive safety analysis as described in Chapter 4. Analysis of safety would be conducted in accordance with DOE procedures for Safety Analysis Reports (current guidance provided in DOE Order 5480.23).

2.2.2.2 Fuel Element Performance Tests in PIPET. The PIPET would be the first self-sustained, power-producing PBR test (see Figure 2.2-2 for a cross section of the PIPET reactor). This test would demonstrate the reactor fuel element operation typical of reactor conditions (power densities, temperatures, pressures, flow rates, and power durations) to support envisioned missions. Data would be obtained on the fuel element, materials, and thermal-hydraulic performance.



Testing Sequence

Figure 2.2-3

PIPET would be used to demonstrate the performance, operability, and reliability of fuel elements developed for the SNTP program. Although this testing would make use of fuel element component verification data from tests in existing facilities to help define the design envelope, such information would not be based on exact simulation of engine system conditions. Due to the unique conditions associated with SNTP reactor designs, the PIPET tests would be the first opportunity to validate the fuel elements. Since a large degree of uncertainty would exist regarding the actual capabilities of the fuel elements and the actual design envelope, design requirements of the PIPET Effluent Treatment System (ETS) (see Section 2.2.3.1) include a provision to handle loss of a complete core under bounding case conditions provided from accident analyses conducted by the program safety team. An outline of the preliminary Safety Analysis Report for PIPET is provided in Appendix D.

The PIPET fuel elements and major components could be shipped to an on-site receiving/assembly building for assembly. A second option would be to ship the assembled devices as one unit. Department of Transportation certified containers are available for either type of shipment. Following receipt and component assembly, pre-operational inspections and testing would be required. Upon completion, the reactor components would be taken to a sub-scale test cell for installation for further pre-operational testing and test operations.

The initial PIPET assembly would consist of typical reactor elements. Supplemental low-power assist elements may also be placed in the PIPET moderator region if necessary to assure a sufficient reactivity margin. Each of the cores could be subjected to 5 operating cycles at a maximum power level of 550 megawatts (MW) for as long as 500 seconds per cycle, with a minimum of 7 days separating each operating cycle at power. Hydrogen, noble gases, halogens, volatiles, and particulates could be present in the exhaust stream. The total inventory of fission and activation products in a PIPET reactor after a 500-second run is shown in Table E-3 in Appendix E.

Cryogenic and ambient temperature hydrogen would be mixed externally to obtain high pressure cryogenic hydrogen, which would then be supplied to the test article. Hydrogen coolant would follow several paths through PIPET. One path would cool the fuel elements with the hydrogen exiting at high temperatures. A second path would cool auxiliary structures (e.g., safety rods, reflector, support structures) with the hydrogen exiting at significantly lower temperatures. Hydrogen would be used for immediate post-test cooling of the reactor core, followed by purging and decay heat removal using helium at moderate flow rates and temperatures.

Engine component tests in the sub-scale facility would be development tests to expose system components to the hot hydrogen and radiation environment. A special nozzle may be installed to tap off hot hydrogen to

feed such propellant management system components as the mixer, the speed control valve, and the turbine. The PIPET radiation environment would be used to expose and evaluate critical flow or control system components.

The remote maintenance and inspection system would be used as appropriate for evaluation of the fuel elements and components between individual tests in a series as well as upon completion of a series. After the last test of a series, the PIPET canister assembly containing the fuel elements would be removed for interim storage on site and possible transport off site for further examination or disposal.

2.2.2.3 Non-Nuclear Engine Integration Tests. EITs would be tests designed to demonstrate proper function of the propellant management system without an operating reactor in the loop. A mock-up of the entire system would be tested using a gas generator system to produce hot hydrogen to power the turbopump for system checkout. The gas generator system would consist of a liquid oxygen/liquid hydrogen combustor, a steam/hydrogen heat exchanger, a liquid oxygen tank, a liquid hydrogen run tank, and a tank pressurizing system. Chill and purge procedures would be developed, and leak checks and functional tests performed. The EIT series would establish confidence in the control and feed system necessary to allow proceeding to the GTA engine system tests. Under current plans, the EIT series would be performed at the validation test station described in Section 2.2.3. The use of existing off-site facilities for portions of the EIT is also being evaluated.

During the EIT, liquid hydrogen at pressures of 310 to 345 kilopascals (kPa) (45 to 50 pounds per square inch [psi]) would be fed into the pump side of the turbopump assembly; the gas generator would produce hydrogen gas of approximately 2,700° K (2,427°C) which would be used to drive the turbine side of the turbopump assembly. Performance of various components at measured pressure, temperature, and flow conditions would be monitored. Waste products consisting of hydrogen and oxygen gases and steam would be vented to the atmosphere. Individual test runs would last from a few seconds to several minutes.

2.2.2.4 Ground Test Article Tests. The GTAs would be a series of up to ten reactors which gradually approach the desired performance conditions. GTA design would evolve from technical information derived during PIPET and other program testing. GTA tests would employ a single cutback nozzle configuration and, through a progressively expanding test envelope, expose the nozzle to the full performance profile values of temperature, pressure, flow rate, and nuclear radiation fields.

Mini-GTA. The mini-GTAs would be designed to be sub-scale versions of the GTA. Subsequent to satisfactory operations associated with PIPET, mini-GTAs would be subject to tests in the same sub-scale test cell used for PIPET.

The mini-GTA reactors would be designed to more closely represent a full size GTA fuel element and would be operated in essentially the same way as PIPET in a sub-scale facility test cell. Approximately five tests, each of 500-second duration at a maximum power level of 550 MW, would be performed on each of the mini-GTAs. The test matrix could potentially generate a fission product inventory in the mini-GTA reactor similar to that generated in the PIPET cores. The total inventory for a 500-second run is shown in Table E-3 in Appendix E.

Full-Scale GTA

The full-scale GTA test series would demonstrate a complete PBR operation with feed and control hardware and a full complement of instrumentation. Multiple tests would be performed on each of the full-scale GTAs. The tests would build up from critical (zero power), to low power, to operational power and temperatures. These tests would demonstrate controllability and stability at full power and rapid start-up and shutdown under computer control over a simulated full mission profile.

The test series would progress from a cold flow test in which the hydrogen gas is passed through the reactor while the core is held in a subcritical condition to tests in which the reactor is held critical at full power levels. Each test would be on the order of a few minutes in duration. The maximum time at full reactor power for any individual core assembly of the GTA test series would be approximately 1,000 seconds. The test matrix associated with each of these reactor cores could potentially generate a fission product inventory (described in Chapter 4) resulting from a single 1,000-second operation at a maximum power level of 2.0 gigawatts (2 million megajoules) (see Table E-4 in Appendix E).

The GTA baseline design includes a turbopump assembly which supplies cryogenic hydrogen to the reactor at the design operating pressures and temperatures. Cryogenic hydrogen for the full-scale GTA test series would be supplied from a large liquid hydrogen tank and pressurized using a turbopump assembly included as a part of the test article. An alternate design would employ a facility pump to supply cryogenic hydrogen from low-pressure storage tanks. The supply system selected would depend upon design trade-offs.

2.2.2.5 Decontamination and Decommissioning. The testing facility would be developed to support PBR technology development activities. However, the same facility may be used to support related research and development

of nuclear propulsion systems for other applications, following appropriate safety and environmental analysis and documentation.

In the event that a period of inactivity should become necessary, the facility would be preserved so that reactivation could be accomplished with a minimum of expense and in a timely manner. All readily accessible areas would be decontaminated to a level allowing general access in accordance with appropriate safety requirements.

Upon completion of usable service, the facility would be decontaminated and the area restored to as nearly an original state as deemed practical by the cognizant authorities at the time. DOE Order 6430.1A (General Design Criteria) would be applied to the design activities to enhance eventual decommissioning activities.

A decontamination and decommissioning plan would be prepared for the PBR validation test facility prior to the acceptance of any uranium-235 (U-235). The plan would be consistent with DOE Order 5820.2A Chapter V, Decommissioning of Radioactively Contaminated Facilities. The decontamination and decommissioning plan would be updated at the completion of testing at the sub-scale level and at the completion of each major test program but no less frequently than every 5 years.

2.2.3 PBR Validation Test Facilities

Demonstration of the PBR propulsion technology requires testing of reactor, nozzle, and propellant management system assemblies, and system integration tests. Because no facility exists that fully meets testing requirements, construction of a new test facility or extensive modification of an existing facility is required. Alternative locations for the test facility were considered and a summary of findings of the Site Narrowing Report is provided as Appendix F. One location at NTS and one location at INEL have been identified as reasonable alternatives for the proposed test facility.

Construction/modification of facilities would be phased to provide a sub-scale facility to accommodate the initial testing. The sub-scale facility would include a single test cell for the PIPET and mini-GTA test reactors as well as the supporting infrastructure. Sub-scale testing would include less than 50 tests over a period of 3 or 4 years. Approximately five tests would be run on each set of fuel elements to be tested. PIPET tests would include some tests to characterize failure mechanisms and margins, in order to resolve safety, performance, and environmental issues accurately.

If the sub-scale testing proves successful, the sub-scale facility would be expanded to provide a full-scale facility necessary to complete the full-scale GTA testing. The full-scale test facility would be designed to accommodate a GTA test reactor with a capacity of 2,000 MW. It is estimated that up to

10 GTA test series would be run. Safeguards and physical security would be provided in accordance with the DOE 5600 series of orders.

The environmental consequences of both the sub-scale and full-scale facilities have been included in this document. Refer to Figure 2.2-4 for a schematic diagram of the PBR validation test facility.

2.2.3.1 Sub-Scale Facility. As shown in Figure 2.2-4, the sub-scale facility would include a control complex including an instrumentation and control system; diagnostic system; a receiving and assembly capability; a test cell; a confinement system; process fluid system, which is comprised of the coolant supply and ETS; interim on-site storage; and a test article transport staging area. The major features of the sub-scale facility are discussed in detail below.

Control Complex

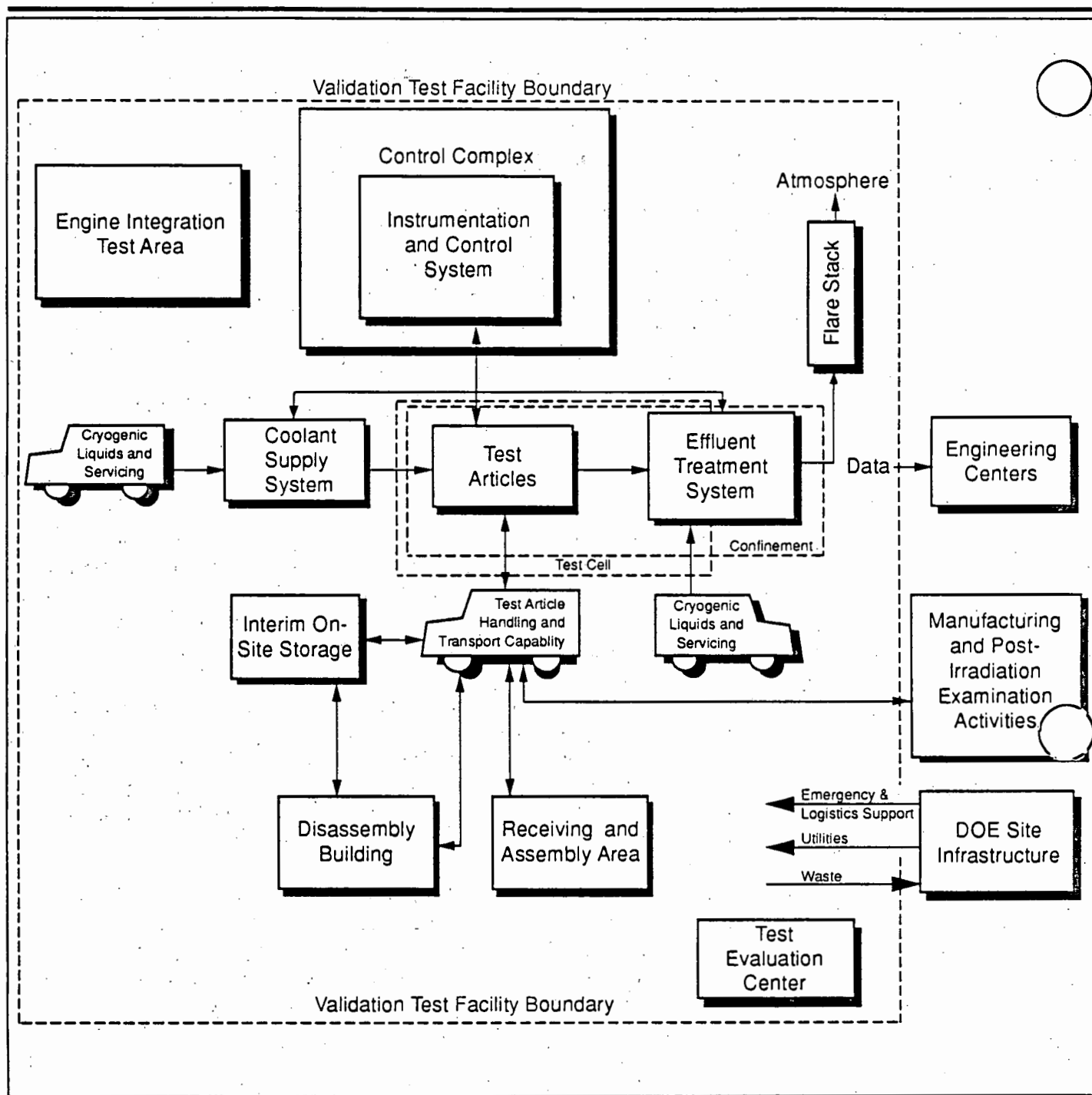
The control complex would be a shielded reinforced concrete building from which access to the test facility, activities involving the test cell, and a system to provide video surveillance over the entire test facility would be controlled. The complex would contain all control consoles associated with the test facility during PIPET, EIT, and GTA operational testing.

Habitability systems would be provided to ensure a safe environment for operations personnel to achieve safe reactor shutdown, decay heat removal, and post-reactor shutdown monitoring during normal operations. Also, should it be necessary after credible accident, these systems would provide the operations personnel with a safe environment in the control complex until they could safely leave.

The fire protection system for the control complex would be designed in accordance with DOE/EP-0108, Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems; Group 2 Ordinary Hazard Occupancy classification; and National Fire Protection Association Standards. These codes and regulations specify all aspects of design which affect fire safety at the test facility.

Instrumentation and Control System

The control system would provide the required safety and control functions for all operations at the test facility. The system would consist of sensors, electronics, actuators, and displays necessary for remote control of all functions associated with the test systems. In addition, the control system would provide visual indication of critical system parameters and process status to assure safe operation during all phases of the experimental programs.



EXPLANATION

Disassembly Building, Test Evaluation Center, and Engine Integration Test Area would not be present in sub-scale facility. Coolant Supply System, Test Cells, and Effluent Treatment System would be expanded in full scale facility.

PBR Validation Test Facility Schematic Diagram

Figure 2.2-4

To prevent an accident from inflicting personal injury or equipment damage, some of the design criteria are as follows:

- Locate the control complex in an area so that in emergencies all critical equipment can be operated safely.
- Provide for an automatic shutdown that would be initiated if a critical out-of-range condition is detected.
- Ensure that remotely controlled components/equipment would move to their safest position (e.g., by spring action) if operational power is lost.

Receiving and Assembly Area

An area would be provided for the major components of the reactor to be tested at the sub-scale level to be assembled and non-nuclear testing of the assembled components to be conducted prior to their being transported to the test cell. Sufficient space would be provided for the normal administrative requirements associated with these activities.

Test Cell

The sub-scale facility would include a test cell to accommodate the initial PBR validation tests (Sandia National Laboratories [SNL], 1990b). Radiation shielding would be provided by thick reinforced concrete walls. The test cell would be designed to accommodate the major components of the reactor and include sufficient penetrations to provide fluids, power, and instrumentation necessary for reactor operations as well as capability to handle and store irradiated material.

Interim On-Site Storage

Additional capability would be provided to accommodate interim storage of irradiated fuel and reactor components pending further evaluation.

Test Article Transport Staging Area

Equipment and space would be provided to allow for the operations required to prepare and package for shipment the irradiated fuel and reactor components for further post irradiation examination activities.

Confinement System

The confinement system would be composed of the necessary equipment and physical barriers to ensure that fission products released to the environment are not in excess of the design fission product release rate.

The confinement barrier in PIPET would enclose the reactor and portions of the ETS. Single failure criteria as defined in 10 Code of Federal Regulations (CFR) Part 50(A) may require additional structures which would be designed to accommodate, with sufficient safe margin, calculated pressure, temperature, and energy loading conditions resulting from normal operations and credible accidents.

Process Fluid Systems

The process fluid systems for the sub- and full-scale test facilities would consist of two major subsystems: (1) the coolant supply system (CSS) and (2) the ETS.

CSS. The CSS would be composed of the hydrogen storage system, the helium storage system, and the pipes and valves for coolant distribution. Siting of storage vessels would be in accordance with Air Force Regulation (AFR) 127-100, Explosive Safety Standards. These subsystems are described below.

Hydrogen Storage System. Three types of hydrogen storage vessels would be required at the test facility: low-pressure liquid hydrogen (LH_2) storage, high pressure cryogenic hydrogen storage, and high-pressure ambient temperature hydrogen storage. The low-pressure LH_2 storage would provide bulk quantities of hydrogen for all test station activities. The liquid and ambient temperature hydrogen would be mixed at high pressure to provide a variable temperature hydrogen flow to the facility test cells during test operations. Gaseous hydrogen (GH_2) would also be used as a pressurant for the high pressure cryogenic hydrogen storage vessels.

The anticipated requirements for the hydrogen storage at the sub-scale facility are as follows:

- Low Pressure LH_2 Storage:
Volume: 110,000 gallons
Pressure: 210-690 kPa (30-100 psi)
Temperature: 20-320 K (-253 to +47° C)
- High Pressure Cryogenic Hydrogen Storage:
Volume: 30,000 gallons
Pressure: 21 megapascals (MPa) (3,000 psi)
Temperature: 20-320 K (-253 to +47° C)
- High Pressure Ambient Temperature GH_2 Storage:
Volume: 10,000 cubic feet
Pressure: 28 MPa (4,000 psi)
Temperature: 250-320 K (+23 to +47° C).

Future expansion of the test facility to the full-scale facility could potentially double the required quantities of hydrogen.

Reactor safety concerns would require that high pressure cryogenic hydrogen be supplied to the test cell by two or more independent systems. Thus the total storage volume requirement would be equally divided among a number of equally sized storage vessels. During normal test operation, each independent system would supply one half the hydrogen flow required by the fuel elements; however, the pipes and valves associated with each independent supply system would be sized to accommodate the total flow required by the reactor fuel. If a failure occurs in one system the other system would increase flow to the reactor fuel and the test would be terminated. Operational limits would be placed on the high pressure cryogenic hydrogen level and the ambient temperature gas storage pressure to ensure that each of the independent systems retains sufficient hydrogen to provide an orderly reactor shutdown, including some of the decay heat removal operations which use hydrogen.

Each of these independent hydrogen supply systems would be protected from projectiles that may result from the rupture of pressure vessels, piping, or the detonation/deflagration potentially associated with a failure in the other systems. This protection would be provided by placing shrapnel barriers in appropriate locations to isolate storage vessels associated with one independent supply system from the vessels of the other. Additional protection for the independent hydrogen supply systems would be provided by placing shrapnel barriers in appropriate locations to isolate the high-pressure hydrogen storage vessels from the other storage vessels (e.g., oxygen) located at the test station.

Helium Storage System. Helium would be used at the test facility for purging storage vessels, pipes, and test articles; for pressurizing certain fluid storage vessels; and for removing decay heat from the test cell subsequent to testing operations. Helium would be stored as a gas at high pressure and ambient temperature. The helium storage vessels would be adequately protected from projectiles by placing shrapnel barriers in appropriate locations to isolate them from the hydrogen and other storage vessels. The high pressure, ambient temperature helium storage requirements for the sub-scale facility are for a volume of 4,700 cubic feet; a pressure of 19 MPa (2,800 psi); and a temperature of 250-320 K (23-47° C).

Future expansion of the initial test facility to the full-scale facility could potentially double the quantity of helium required.

Coolant Distribution System. The fluids distribution system (pipes and valves) would supply hydrogen and helium to various locations at the test facility in appropriate quantities to support test and operational activities. Auxiliary equipment required by the fluids distribution system would include

vaporizers to maintain pressure on the bulk LH_2 storage vessels during transfer operations, facility pumps and vaporizers to enable filling the high pressure ambient temperature hydrogen storage vessels, filters at the fill stations and test cell to maintain fluid cleanliness, instrumentation to monitor conditions in the storage vessels and distribution systems, and mixers to deliver variable temperature hydrogen to the test cell. The pipes, valves, and associated components of the fluids distribution system would be designed to operate in the range of 690 kPa (100 psi) at 20 K (-253° C) for low pressure LH_2 lines to 41 MPa (6,000 psi) at 320 K (47° C) for GH_2 lines.

Isolation valves would be located at the inlets and outlets of all pressure vessels. Remotely actuated or pressure regulating valves would be used to control the pressure in the storage vessels. Pressure relief devices would be incorporated into the design of the isolation system to avoid over-pressuring the storage vessels. Pressure relief devices would also be incorporated into the design of any feed line that may be isolated when carrying liquid or cryogenic hydrogen.

Large quantity releases of hydrogen would be vented to a coolant flare stack. Operations that are expected to release large quantities of hydrogen are cooldown of the liquid hydrogen storage vessels, fill of hydrogen storage vessels, and post-operational purge of hydrogen feed lines. The flare system would be designed and sized as appropriate for the range of expected flow conditions resulting from these operations.

Effluent Treatment System. There are three major reasons for incorporating an ETS into the test facility. First, one of the goals of PIPET testing is to validate design margins. The potential for releasing a larger quantity of fission products increases as the operating parameter approaches these limits. The emissions of radionuclides into the ambient air from DOE facilities are regulated by the National Emission Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61 Sub-Part H), which specifies that the emissions shall not exceed an amount that would cause any member of the public to receive in any year an effective dose equivalent of 10 millirem per year. While the NESHAP may allow a member of the public to receive a dose of 10 mrem in a year, the SNTP program would be committed to a design goal of 2 mrem per year, or 20 percent of the allowable regulatory limit. Second, because the SNTP program is a developmental program, there would be some uncertainty in the actual composition of the effluent. An ETS would ensure that the emissions from planned activities would remain within the program goals under all postulated routine operating scenarios. Third, it is a national policy to reduce radioactive discharges to a level that is as low as reasonably achievable (ALARA). The ETS would be designed to reduce releases of

noble gases (xenon and krypton); halogens (iodine), volatile elements, and other fission products in the form of particulates¹.

The ETS would be designed to accomplish the following objectives:

(1) ensure that radioactive material entering the ETS remains in a subcritical geometry; (2) cool the test article effluent to temperatures acceptable for normal engineering materials used in gas treatment systems; (3) remove particulates and debris from the effluent stream; (4) remove halogens, noble gases, and vapor phase contaminants from the effluent stream; and (5) flare the resulting hydrogen gas to the atmosphere. The effluent would pass through the ETS in 5-10 seconds, although the noble gases would be removed and retained for several days to allow decay of the short-lived isotopes.

The ETS would be designed in a manner such that during test operations and under accident conditions (including consideration of any impacts associated with the accumulation of radiological material in the ETS) the releases are reduced to limits derived from exposure limits for workers and the public given existing guides, regulations, standards, etc. Further, it is the policy of the program that the releases be reduced below these established limits to ALARA, considering technical, economic, and practical constraints.

Preliminary contaminant retention goals have been established to allow initiation of the ETS design effort. These are:

1. To remove 99.9 percent of the most penetrating size of solid phase contaminants (particulate and condensed phase contaminants less than 100 microns) from the effluent stream
2. To remove 99.5 percent of the gas (iodine, xenon, and krypton) and vapor phase contaminants from the effluent stream.

The stated removal efficiencies are not, at this time, intended to be interpreted as the final performance requirements for the ETS. Analysis will be performed to determine the release limits required to satisfy existing guides, regulation, standards, etc. These limits, when considered in conjunction with projected normal operating and accident scenarios, potential contaminant source terms and the ALARA principle of the program, would be used to establish the final removal efficiencies of the ETS.

The stated 99.9 percent solid and 99.5 percent gas and vapor phase removal efficiencies are within the envelope of the current state of the art for filter and adsorption media. Typical air filtration efficiencies for high

¹ Appendix E shows the total expected fission product inventory of the testing activities. Chapter 4, Section 4.12, describes the expected radiological effects as a result of release from the ETS.

efficiency particulate air (HEPA) filters exceed 99.95 percent of the most penetrating particle size. Based upon data contained in Los Alamos National Laboratory (1973), the Nuclear Furnace-1 test program at Nevada Research and Development Area (NRDA) in Nevada demonstrated krypton retention efficiencies in excess of 99.5 percent. It should be noted that xenon and iodine are much more readily adsorbed than krypton. Thus the performance level defined for krypton is conservative for xenon and iodine.

The elements of a conceptual ETS which could meet these goals are presented in Figure 2.2-5 and described in the following paragraphs.

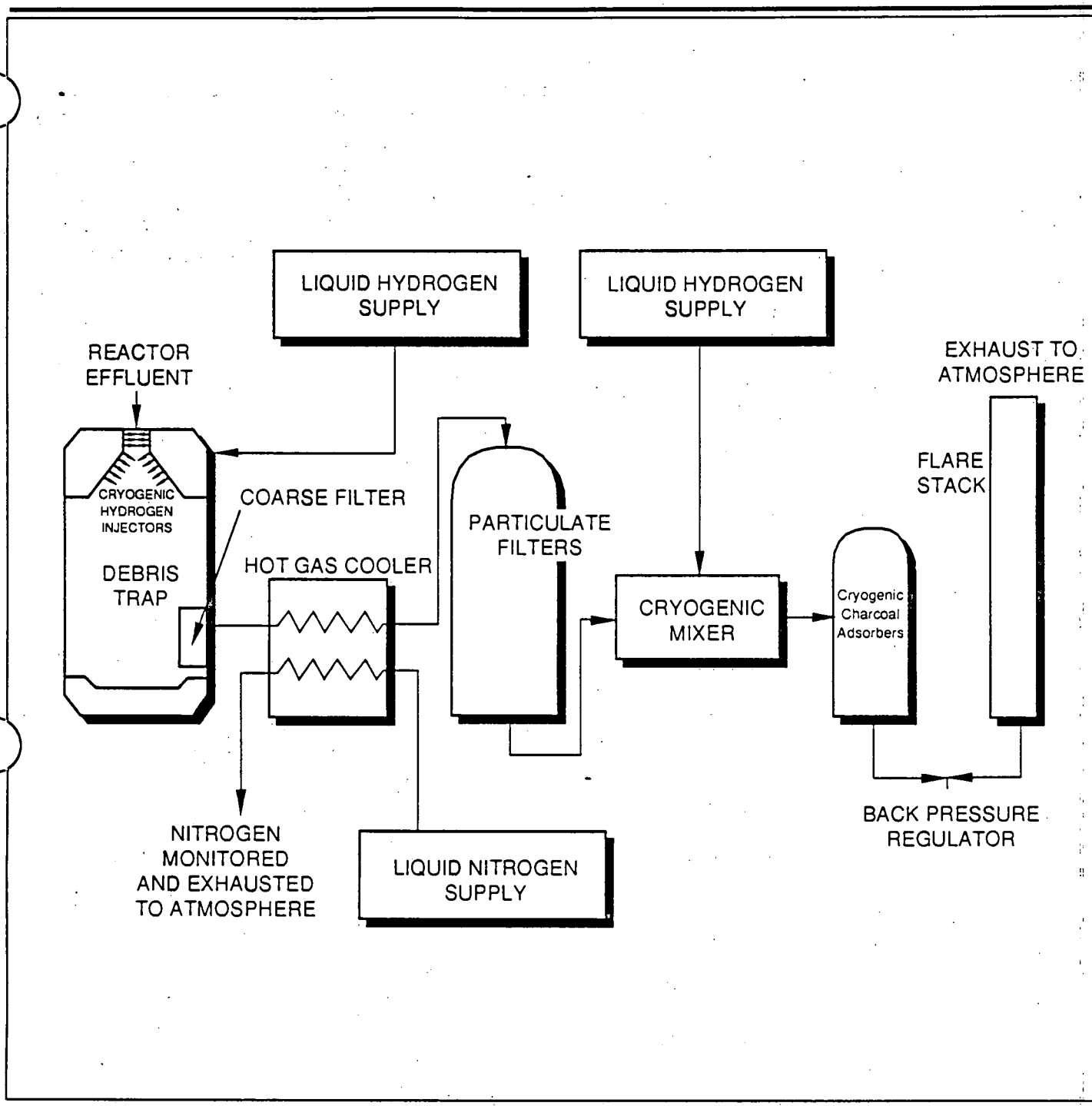
Cryogenic Hydrogen Injection. Large quantities of cryogenic hydrogen would be injected directly into the effluent stream and lower the temperature through bulk mixing. The required coolant flow rate would be established by the power generated by the test article.

Debris Trap. A debris retention device would be incorporated into the ETS design to collect any debris that may be produced by failed fuel elements and to divert the effluent flow. This device would be designed to ensure that the material retained within it would be maintained in a subcritical configuration. It is anticipated that the majority of debris resulting from a fuel element failure would remain in the debris retention device. The debris trap would be designed to be cooled so that it may be constructed using conventional engineering materials.

Hot Gas Cooler. A gas-to-gas heat exchanger would use low temperature nitrogen to pre-cool the effluent prior to removing the noble gases. The nitrogen would be supplied from bulk liquid storage vessels. Nitrogen exiting the hot gas cooler would be monitored for contaminants and exhausted to the atmosphere. Preliminary calculations indicate that inclusion of this component could reduce the flow rate downstream of the final mixer by half.

Particulate Filter. The effluent would then be passed through filter media designed to remove 99.9 percent of the most penetrating size of the remaining particulates (nominally 0.3 microns) from the stream. In addition to the efficient removal of small particles entrained in the effluent stream, the filters would also provide a certain amount of redundancy for larger particles which escape the debris retention device. Granular, sintered metal and HEPA filters, as well as other media, are being considered to perform this function.

Cryogenic Mixer. The effluent stream must be cooled to cryogenic temperatures to remove the radioactive noble gases and halogens. This final cooling would be performed by injecting cryogenic hydrogen into the effluent stream.



Conceptual Effluent Treatment System

Figure 2.2-5

Cryogenic Charcoal Adsorbers. Cryogenic adsorption beds and cold traps are under consideration for use to remove 99.5 percent of the halogens and noble gases from the effluent stream. The performance of the cryogenic adsorption beds is a function of the bed temperature, the total bed volume, and the volumetric gas flow through the bed. The bed design must consider these parameters to ensure retention of the radioactive halogens and noble gases. The applicability of cold traps may be limited due to the very low anticipated concentration of the contaminants.

Since cryogenic adsorption beds and cold traps provide only temporary retention of radioactive gases, a final collection and/or disposal method must be included in an effluent processing system. Retention of these gases for several days allows for decay of the short half-life constituents and results in a significant reduction of radioactive discharge to the environment. One option would be to isolate the cryogenic beds and/or cold traps and vent the gases to a cryopump. This concentrated waste would then be disposed of appropriately. For purposes of analysis, isolation of the absorption beds and/or cold traps and decay of the radioactive gases followed by a controlled release to the atmosphere was evaluated as the bounding condition.

Flare Stack. Finally, the remaining treated effluent would be vented and combusted through a flare stack. Intentional burning of the remaining hydrogen effluent would prevent the accumulation and potential detonation/deflagration of the hydrogen in the vicinity of the test cell.

An effluent monitoring system would measure the radioactive and particulate content of the discharge stream on a real-time basis in the various ETS stages and as released to the environment. This would alert the operator to releases of radioactivity and/or particulates approaching prescribed limits (i.e., Technical Safety Requirements and NESHAP). In addition, the monitoring system would allow for initiating methods to prevent or minimize potential releases (e.g., terminate test, isolate the filter or absorber having degraded performance, etc.), and would also provide post-run quantitative estimates of total releases made to the environment during each run.

A number of the ETS components (potentially including but not limited to the debris trap, filter media, and adsorber beds) may become sufficiently radioactive to require special maintenance, testing, and inspection procedures to minimize occupational exposure. Features to expedite all required procedures would be incorporated into the design. The ETS design would include appropriate shielding to prevent worker exposure to ionizing radiation above acceptable levels. In addition, compatibility with special equipment such as portable shielding and remote inspection and maintenance equipment would be incorporated into the design as necessary.

Due to the ETS function as a portion of the radionuclide confinement system, it would be designed and constructed with a level of redundancy and reliability appropriate for safety. In addition, the system would be designed to satisfy the single failure criteria as adopted by the program for the confinement function and systems.

2.2.3.2 Full-Scale Facility. Several additions and modifications to the sub-scale facility would be required to create a full-scale facility (see Figure 2.2-4). Modifications include increasing the fuel storage capacity to accommodate the larger GTA test article's requirements. Additions include providing separate consoles for each testing activity, a test evaluation center to accommodate data acquisition requirements and a disassembly building to enable limited on-site post-irradiation activities. The CSS and ETS would be expanded and a test complex would be provided as needed.

Test Complex

The test complex would be expanded or modified as necessary to test several GTAs (up to 10). The GTA test location(s) would accommodate test articles and provide the necessary fluids, power, instrumentation, and effluent treatment.

At INEL the existing facility, if it can accommodate GTA testing, would be used to support additional tests by moving the GTA test article to storage after a test and installing a new GTA test article in the facility. If the CTF proves to be inadequate, additional test cells would be constructed to accommodate the proposed testing. At the NTS, construction of additional test cells would be required.

Disassembly Building

A disassembly building with an integral hot cell would be required to accommodate initial disassembly and post-irradiation activities for irradiated fuel elements or test reactor assemblies. The building would have a shielded area for unloading each test article from the cask used to transport the assemblies from the test cell.

EIT Area

Space would be provided within the full-scale test facility to accommodate testing of liquid hydrogen flow components for integration into the engines. Conceptual estimates indicate that an area of approximately 1,600 square feet would be required to accommodate this testing. This testing area would provide appropriate blast protection in accordance with AFR 127-100.

Expanded Process Fluids

During the full-scale facility expansion, additions will be made to the process fluid systems for supplying coolant and treating effluent. A second ETS or major expansion to the sub-scale ETS would be constructed for GTA operations. The full-scale ETS would incorporate information gathered from the sub-scale ETS operation.

Test Evaluation Center

The Test Evaluation Center will provide office and computer/laboratory work space for the engineering team required to analyze the data generated during system tests. It will be located near the test facility, but far enough away that it can be occupied routinely when radioactive test articles are located in the test cells. It would typically be evacuated during power test operations.

2.2.4 Employment and Population

Construction and/or modification of all facilities is expected to take approximately 18 to 24 months for both the sub-scale and full-scale test facilities, with an average work force of about 35 and a peak work force of about 100. The number of personnel on site during pre-operational activities at the sub-scale facility would be limited to about 30 security, technical, administrative, and maintenance personnel. The pre-operational staff of the full-scale facility would be approximately 50 to 60. During actual testing operations for both facilities, the number of personnel on site would be reduced to a minimum operating staff of no more than 10 individuals, all located within the control complex. The resulting population increase in the region would be approximately 70 as a result of sub-scale operations and an additional 50 as a result of full-scale operations.

2.3 DESCRIPTION OF SITING ALTERNATIVES

Two sites at DOE installations have been identified as suitable locations for the PBR validation test facility: the SMTS site at the NTS and the CTF site at INEL. The principal exclusionary criteria considered in the site narrowing process were (1) similar nuclear activities conducted at the installation; (2) 15 kilometers (9.3 miles) minimum distance to the nearest urban area; and (3) federal ownership of the facility. Both of the DOE installations have sufficient infrastructure support. The SMTS site would require new construction for all facilities and the extension or improvement of roads and utilities. The CTF site has existing facilities and infrastructure but would require some modifications to existing facilities as well as some new construction. Both sites would require maintenance, testing, waste management, and ultimate disposition or decontamination of the test facility (The Harris Group, 1991).

2.3.1 SMTS

The SMTS (Figure 2.3-1) is located in the center of NTS, south of Mine Mountain Road and west of Saddle Mountain Road (Figure 2.3-2). Distances to the NTS boundaries from SMTS are as follows: north 22 miles, south 19 miles, east 14 miles, and west 14 miles. Access to the test area is controlled by the Safeguards and NTS Security Branch of the Nevada Field Office Safeguards and Security Division (SNL, 1990e).

2.3.1.1 Facility Description. Selection of the SMTS would require new construction for sub-scale and full-scale test facilities, as described in Section 2.2.3 and as shown in Figure 2.2-4. Other infrastructure required for the site includes power lines, phone lines, roads, a deep water well, and water storage tanks. Transportation improvements include new site roads and grading of existing access roads.

2.3.1.2 Infrastructure Requirements

Power and Telephone Lines

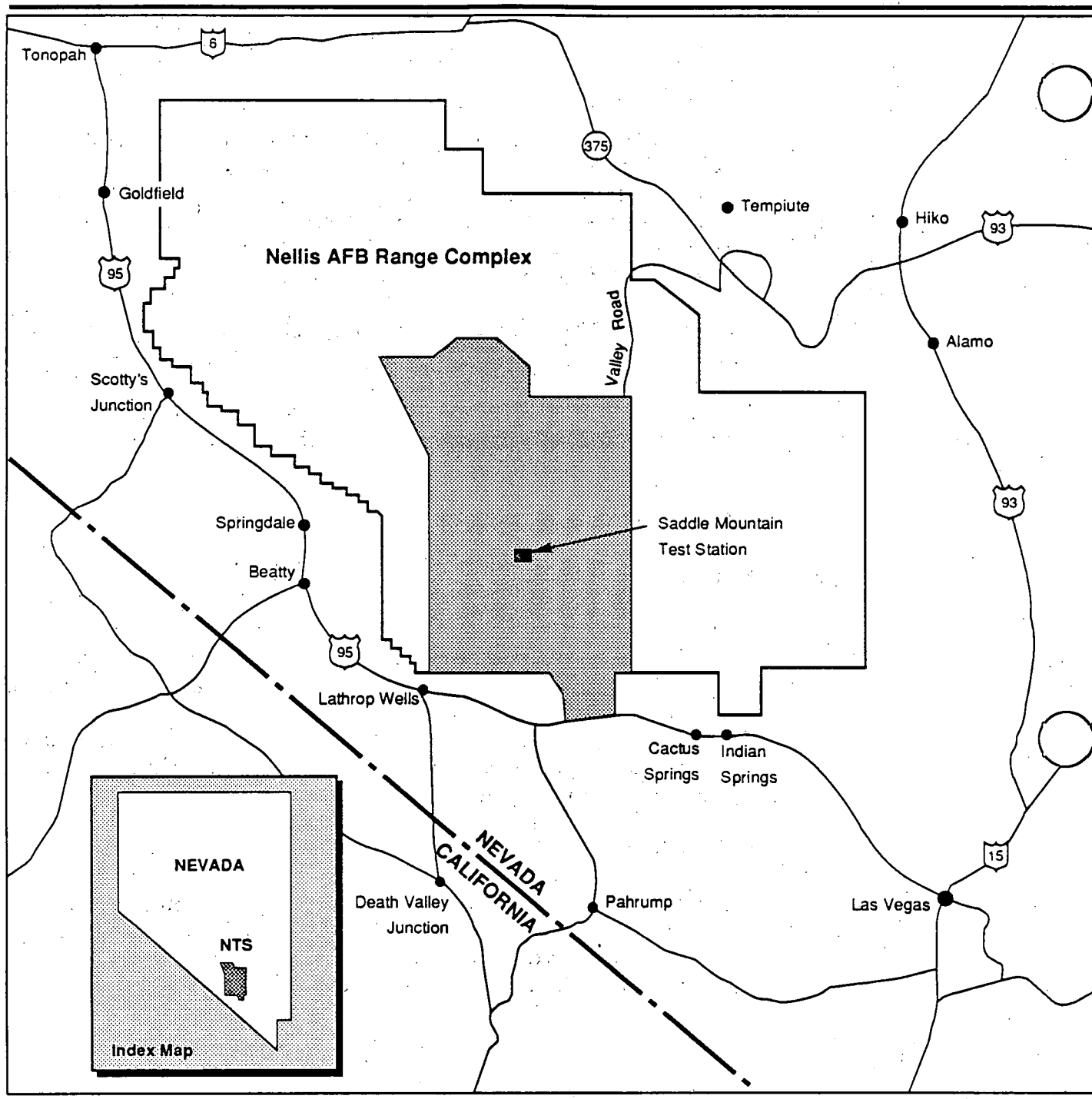
A 34.5 kilovolt (kV) overhead power distribution line approximately 2.4 miles long would be required to connect the facility to the existing 138 kV power transmission line along Mine Mountain Road. The installation of a stepdown transformer would also be required. Additional short-term electrical capacity which may be needed for the SMTS could be provided by large transportable generators. A telephone line approximately 2 miles long would be required to tap into the existing telephone lines.

Sanitary Sewage System

A sanitary sewage system would be required for the peak 50 to 60 person on-site staff during test preparation. The most appropriate system for the site would be an on-site septic system. It is anticipated that less than 2,400 gallons per day of sanitary waste would be produced.

Water Supply

Water would be provided from an existing 3,680-foot deep, large diameter exploratory drill hole located near the center of Mid-Valley, about 2.1 miles southeast of the SMTS. The well is not used for water supply purposes for any other activities at NTS. Pumping depth would be at about 2,000 feet below the surface. For construction and the sub-scale tests, a sunlight treated polyvinyl chloride water supply line to the SMTS would be laid on the ground surface and a portable generator would be used to power the pump for replenishing the water tank. For the full-scale systems tests, consideration would be given to constructing a 1.5-mile long buried water line. Wellhead development would consist mainly of laying a concrete pad



EXPLANATION

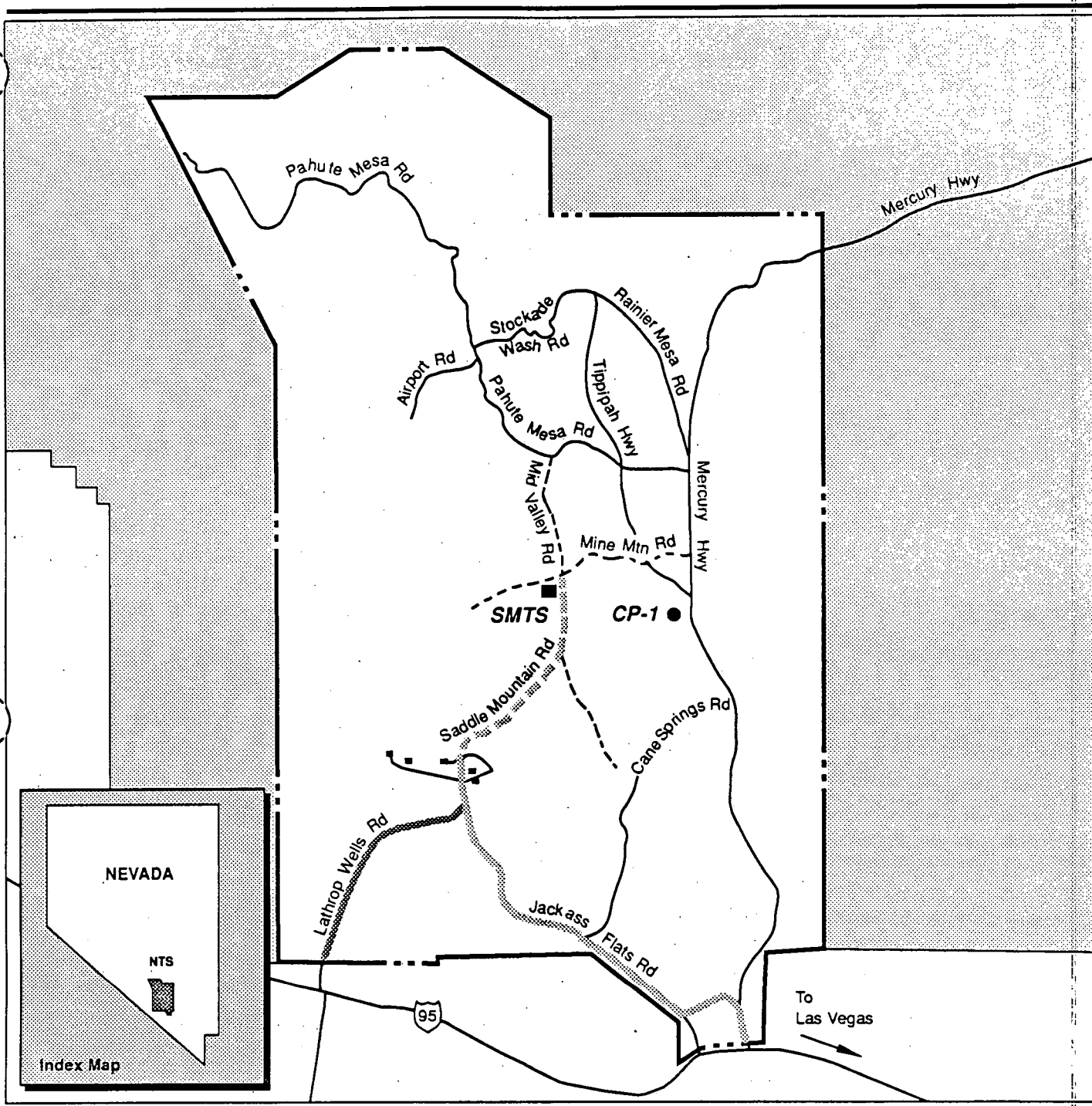
 Nevada Test Site (NTS)

Nevada Test Site



Figure 2.3-1





EXPLANATION

----- Two Lane Gravel Road	----- Primary Access Roads
———— Paved Roads	----- Alternate Access Road
----- Nevada Test Site	
Nellis Air Force Range	

Nevada Test Site

Saddle Mountain
Test Station



Figure 2.3-2

and installing necessary pipes and valves. Access to the wellhead is by an existing unimproved road. Water would be stored in two 250,000-gallon storage tanks which would be placed in an elevated area of the site.

Excavation

Construction of the test facility would require earth removal and fill for the test site and water tank installation and grading of the roads. The cut and fill required are approximately 26,000 cubic yards and 37,000 cubic yards, respectively. The total area disturbed at SMTS is anticipated to be less than 100 acres.

2.3.2 CTF

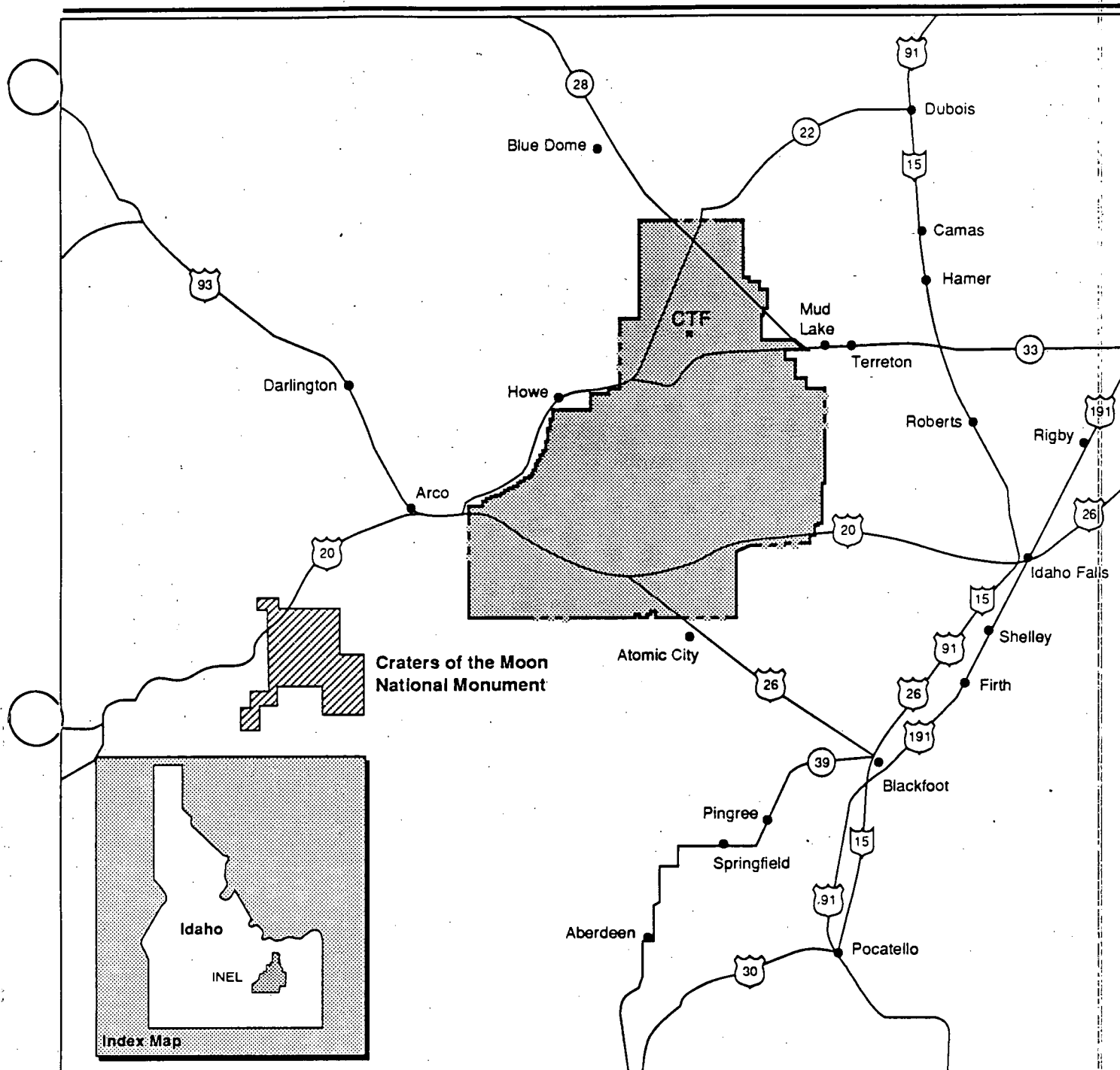
The CTF (Figure 2.3-3) is located in the northern portion of INEL, northeast of the intersection of Lincoln Boulevard and State Highway 33 (Figure 2.3-4).

Some existing facilities to support PBR validation testing are already located at the CTF site. Approximate distances to the INEL boundaries are as follows: north 11 miles, south 28 miles, east 11 miles, and west 8 miles.

2.3.2.1 Facility Description. Existing facilities at the CTF site consist of a receiving/assembly/hot cell facility, a certified American Society of Mechanical Engineers pressure vessel (containment structure rated to 40 psi), a control bunker, post-irradiation examination facilities, and administrative space. An approximately 1.6-mile railroad track connects the containment structure to the receiving/assembly/hot cell facility. A security fence with guard stations is also in place.

A number of modifications to the existing facility would be required. It is likely that the control building would have to be reconfigured to accommodate the tests. The receiving/assembly/hot cell facility may require modest modification to accommodate the hot test articles. The hydrogen and helium storage area would probably be located to the north of the CTF. For the sub-scale tests, portions of the ETS would probably be located within the CTF, with the hydrogen and nitrogen supplies located to the east of the CTF. Engineering studies have been initiated to determine if the CTF or new test cells would be required for the full-scale test. New test cells, if required, would be located adjacent to the CTF.

Use of the CTF containment structure as the test cell would require construction of process fluids storage and piping, the ETS, and the flare stack. The test article would be secured to one of the special rail cars moved to the CTF containment structure and connected to coolant fluids and the ETS. Following the test and after a cool-down period, the test article could be moved directly to the hot-cell facility for disassembly and



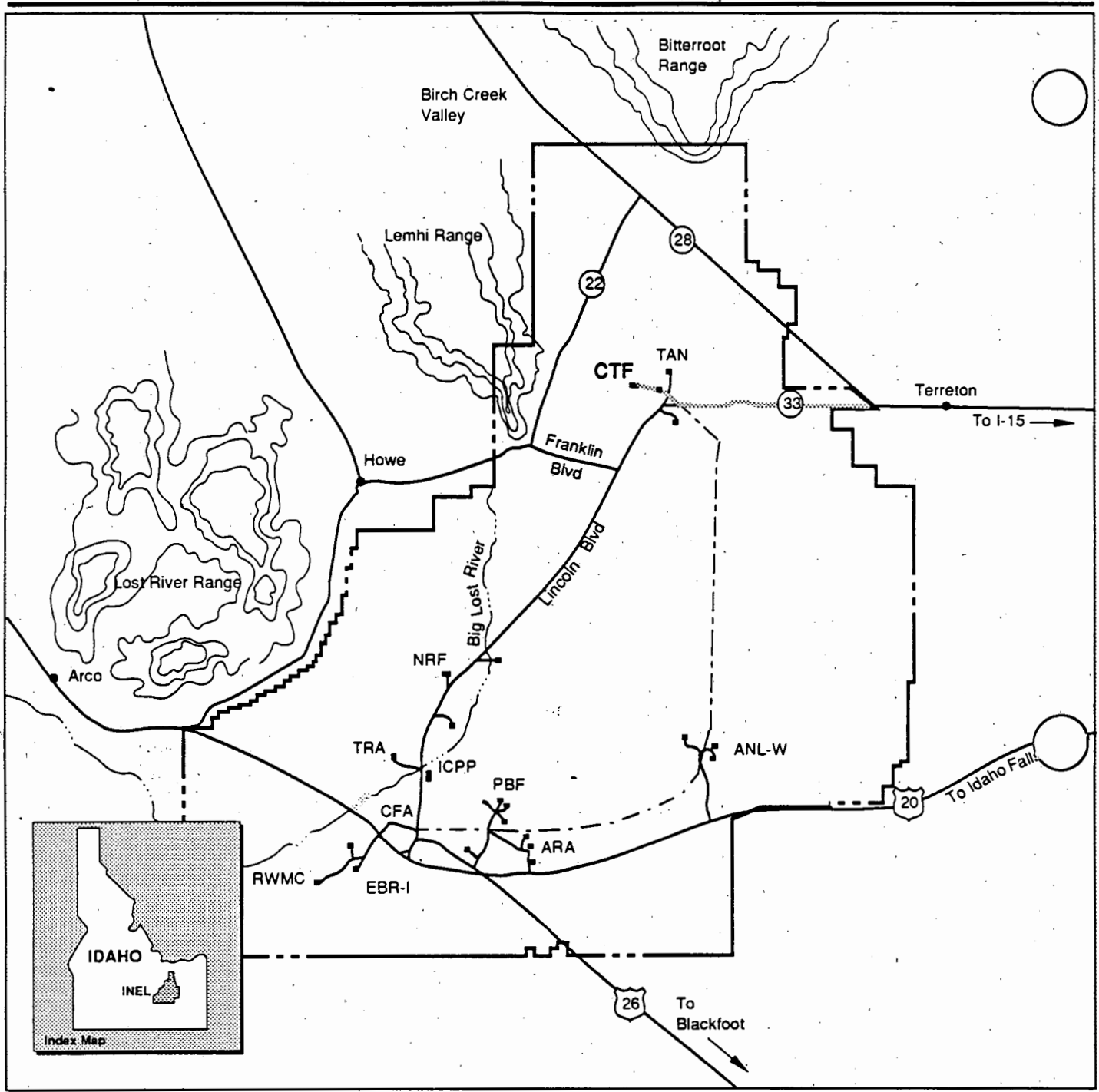
EXPLANATION

-  Idaho National Engineering Laboratory
- CTF** Contained Test Facility

**Idaho National
Engineering
Laboratory**



Figure 2.3-3



EXPLANATION

- Transmission Line
- Paved Roads
- Access Road

- ANL-W - Argonne National Laboratory West
- ARA - Auxilliary Reactor Area
- CFA - Central Facility Area
- CTF - Contained Test Facility
- EBR-I - Experimental Breeder Reactor-I
- ICPP - Idaho Chemical Processing Plant
- NRF - Naval Reactors Facility
- PBF - Power Burst Facility
- RWMC - Radioactive Waste Management Complex
- TAN - Test Area North
- TRA - Test Reactor Area

**Idaho National
Engineering
Laboratory**

**Contained Test
Facility**



Figure 2.3-4

post-irradiation examination. Engineering studies are underway to determine renovation requirements for the CTF vessel to provide for coolant flow, debris collection, exhaust of propellant, purging, inerting, and venting.

2.3.2.2 Infrastructure Requirements. Infrastructure required for the activities is already in place at the site. This includes paved roads, power lines, telephone lines, a sanitary system, and a water supply. Intermittent PBR validation testing may require closure of State Highways 33, 28 or 22 for short durations of less than 1 hour. Traffic would be rerouted to the two open highways.

Excavation

Modification and construction of the test facility would affect less than 50 acres of previously disturbed land adjacent to the containment structure. Cut and fill requirements are approximately 3,000 and 4,000 cubic yards, respectively.

2.3.3 Transportation of Hazardous and Radioactive Materials

Various quantities of gaseous helium (GHe), LH_2 , liquid nitrogen (LN_2), and liquid oxygen (LOX) would be required for PIPET, EIT, and GTA tests. Table 2.3-1 lists the source locations of GHe, LH_2 , the number of trips, and the transportation requirements to supply these materials to both the SMTS and CTF, since sources for these gases are limited. LN_2 and LOX may be found from local suppliers.

Table 2.3-1. LH_2 /GHe Transportation Options

Materials	Potential Source	Destination	Miles	No. Trips	Total Miles
GHe	Kelly AFB (San Antonio, TX)	SMTS	1,375	405	556,875
GHe	Kelly AFB (San Antonio, TX)	CTF	1,600	405	648,000
LH_2	Air Products (Sacramento, CA)	SMTS	500	225	112,500
LH_2	Air Products (Sacramento, CA)	CTF	800	225	180,000
LH_2	Air Products (Tonawanda, NY)	SMTS	2,375	225	534,375
LH_2	Air Products (Tonawanda, NY)	CTF	2,100	225	472,500
LH_2	Linde Corp. (Ontario, CA)	SMTS	300	225	67,500
LH_2	Linde Corp. (Ontario, CA)	CTF	925	225	208,125

Quantities of the gases for each test are as follows: for each PIPET test, 900,000 cubic feet of GHe, 250,000 gallons of LH_2 , and 250,000 gallons of LN_2 would be required. Preliminary estimates indicate that for each EIT,

2,100,000 cubic feet of GHe, 300,000 gallons of LH₂, and 5,000 gallons of LOX would be required. For each GTA test, 7,200,000 cubic feet of GHe, 2,000,000 gallons of LH₂, and 2,000,000 gallons of LN₂ would be required.

The number of trips and transportation requirements for U-235 is discussed in Appendix E. The impacts of potential accidents involving the transport of U-235 are discussed in Section 4.12.2.4.

2.4 NO-ACTION ALTERNATIVE

Under the No-Action Alternative, the Air Force would not proceed with the SNTP program. Component assembly, fabrication, and validation testing would not be carried forward, and the PBR-propelled rocket technology would not be developed or validated.

2.5 ALTERNATIVES ELIMINATED FROM FURTHER CONSIDERATION

Early in the SNTP program planning, several other alternatives were considered but were eliminated as unacceptable. These alternatives are briefly discussed below.

2.5.1 Alternative Propellant

One alternative considered but not carried forward would be to use helium rather than hydrogen as the propellant. Helium is not a suitable coolant for the fuel elements at high power. Since the specific heat of helium is lower than that of hydrogen, a higher helium flow rate is required to remove a given quantity of heat. The higher helium flow rate, in conjunction with its higher molecular weight, results in a pressure drop across the fuel element, for any given operating power, that is higher than that for hydrogen. At a sufficiently high power level, the helium pressure drop may threaten the integrity of the fuel element. In addition, the specific impulse (Isp) of a rocket engine is inversely proportional to the square root of the molecular weight of the propellant. Thus, the use of helium as a propellant would result in an Isp that is about 70 percent of that for hydrogen (Hill and Peterson, 1979). Even if lower Isp was acceptable, liquid helium would require storage and handling at a temperature of approximately 4 K (-269° C), a substantial increase in complexity over hydrogen storage requirements at 20 K (-253° C).

2.5.2 Materials and Components Testing Alternatives

2.5.2.1 Simulation of Testing and Operating Conditions. Another alternative considered but not carried forward would be the simulation of testing and operating conditions in place of physical testing. The performance of materials, components, and assemblies could be simulated by computer codes. Significant simulation is presently included in the

program and extending this effort would be possible. However, simulation of testing and operating conditions does not allow validation of component performance and, therefore, would not meet program goals.

2.5.2.2 Integrated Bench Scale Tests. Another alternative considered but not carried forward would be to perform only bench or laboratory scale tests that incorporate PBR technology and not conduct testing at the sub-scale facility. The use of this alternative to develop the PBR technology would not fully demonstrate the viability of the concept. Many of the key technical issues relate to fuel or fuel element performance under typical reactor operating conditions. For the PBR, these conditions can only be simulated on a complete fuel element in the sub-scale facility. Bench or laboratory scale tests are anticipated to be a key part of development work leading up to the sub-scale facility but not to replace it.

2.5.2.3 Continued Research and Development of Components and Assemblies. Another alternative considered but not carried forward is to continue research and development of the rocket components and assemblies until more data are available on the new technologies being developed. This would extend the schedule without moving toward meeting the objectives of the program.

2.5.3 Alternative Locations

2.5.3.1 Initial Site Screening. The initial screening began with a review of continental United States locations that were federally owned sites and had access control systems in place. The sites were screened further for similarity of operations. Several Department of Defense sites were considered (e.g., Tonopah Test Range, Nevada, and Edwards Air Force Base, California) but none hosted similar nuclear research operations. The remaining sites were all DOE sites.

Early in the site narrowing process, several candidate locations within the Nevada Test Site were evaluated for use as a PBR validation test station. With the exception of some existing facilities at the NRDA (formerly referred to as the Nuclear Rocket Development Station), the remaining candidates were dismissed due to unfavorable topography, inaccessibility, or refurbishment efforts which were obviously significant and considered uneconomical. Major components of the NRDA test facilities had been removed and reapplication for PBR testing was not considered reasonable. Only the engine maintenance and disassembly facility (E-MAD) was considered to be a reasonable candidate to support validation test activities. However, the costs to refurbish the E-MAD facility so a relatively small part of it would be available to support PBR validation were estimated to be several times that of shipping irradiated specimens to an existing hot cell facility for the post irradiation examinations. The program concluded that this latter approach was a more cost-effective method of conducting post

irradiation examination and would reduce the overall construction impacts by eliminating an extensive renovation effort and only building a small facility capable of stabilizing these specimens prior to transport. Finally, the entire NRDA is habitat for the desert tortoise which is a federally protected threatened species. The mitigation process to conduct limited operations within this habitat was considered to introduce additional complexities into the technology validation program.

The second step was the exclusion of sites located less than 15 kilometers (9.3 miles) from urban areas. This resulted in the elimination of all but four sites.

The remaining sites at Hanford (Richland, Washington), INEL, NTS, and Savannah River Site (SRS) (Savannah, Georgia), were then evaluated for mission compatibility. The Hanford Site was excluded for incompatibility with existing operations; no suitable 100-acre location was available that was compatible with existing or planned operations. The entire installation is currently undergoing environmental restoration in accordance with a memorandum of agreement with the state of Washington. SRS also was eliminated due to incompatibility with existing operations. SRS produces plutonium, tritium, and other nuclear materials for United States defense programs. SRS is currently the primary source for tritium production in the United States. The need to maintain separation between the SNTP test facilities and tritium production facilities would not allow appropriate siting of the project at SRS. SRS is surrounded by wetlands in the south and east and is bisected by public roads to the north. Alternate locations would have required siting on special status lands and would have increased public safety concerns. Two sites at INEL (Quest and CTF) and one site at NTS were retained for further study.

2.5.3.2 Quest Site. Although the Quest site was considered a viable alternative when this environmental analysis process began, it has since been eliminated from consideration, and is not analyzed further in this EIS. The rationale for this decision, which was made by the Air Force in May 1992, is outlined in this section. (more detailed background information is contained in Appendix G).

The Quest site is in an undeveloped, remote area located in the east-central portion of INEL. Because earlier surveys along the road leading to the Quest site led to the discovery of many prehistoric archaeological sites, the Air Force commissioned a survey of the Quest site area that could be affected by construction of the PBR validation test facility. This survey, which was performed by Air Force contractor archaeologists in April 1992, revealed the presence of an unusually high number of diverse cultural materials. Included among the finds was an extensive scattering of lithic and ceramic materials with features that included hearths and associated fire-cracked rock; pottery sherds; burned bone/tooth enamel fragments associated with lithic

materials; an extensive packrat midden; and chinked stone walls of undetermined purpose that are unique on INEL. These discoveries are consistent with site types that include hunting locations, field camps where game processing occurred, and tool modification areas. Additionally, the packrat midden is similar to those that have, in the past, revealed important paleontological remains.

Because of the amount, richness, and diversity of the cultural materials found, the Quest site (virtually all of which has, to date, escaped disturbance) has the very definite potential to contribute significantly to an understanding of North American and Idaho prehistory. Many of the sites are consequently likely to be eligible for inclusion in the National Register of Historic Places.

The potential importance of the Quest site from a cultural resources standpoint has convinced the Air Force that it would be imprudent to continue to carry the Quest site as an alternative location for the PBR test facility. Although the Air Force could, consistent with current cultural resources laws and regulations, perform data recovery at the Quest site and thereafter proceed to construct the proposed test facility, this would result in the loss of these prehistoric sites forever. Because alternative suitable locations for the PBR validation test facility exist, the Air Force has concluded that this potential destruction of what appear to be significant prehistoric sites is unwarranted. Consequently, in late May 1992, the Air Force eliminated the Quest site from further consideration and analysis in this EIS.

2.6 OTHER FUTURE ACTIONS IN THE REGION

No reasonably foreseeable actions were identified at either site which could be considered as contributing to a potential cumulative impact on the environment.

2.7 COMPARISON OF ENVIRONMENTAL IMPACTS

Environmental impacts are summarized in Table 2.7-1.

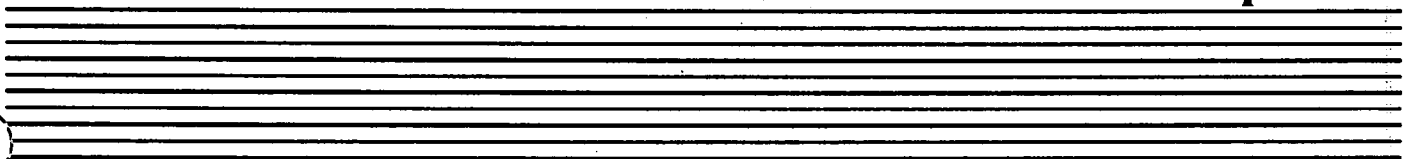
Table 2.7-1. Summary of Impacts from Alternatives

	SMTS	CTF	No-Action
Local Community			
Land Use	No impact	No impact	No impact
Population	263; less than 0.04% increase	263; less than 0.2% increase	No impact
Employment	100 personnel; 2% increase	100 personnel; less than 1% increase	No impact
Transportation	Maximum of 5.9% increase in AADT	Maximum of 6.1% increase in AADT	No impact
Utilities			
Water	Less than 0.5% increase in withdrawal	Less than 0.1% of allocation	No impact
Electrical	New distribution line to the site required; 0.75 MW peak power requirement	Less than 1% of existing capacity required	No impact
Wastewater	2400 gal/day: septic system/leachfield to be constructed	2400 gal/day: less than 1% of existing capacity to be used	No impact
Solid Waste	Less than 1% increase	Existing and proposed new landfill sites contain sufficient capacity for solid wastes	No impact
Hazardous Materials/Waste			
Materials	Shipment of less than 220 pounds of U-235 per year (as part of component assemblies)	Shipment of less than 220 pounds of U-235 per year (as part of component assemblies)	No impact
Waste	Less than 2% increase per year	Less than 1% increase per year	No impact
CERCLA	No impact	No impact	No impact
Radioactive Materials	Approximately 18% of existing capacity for storage of low-level solid waste required	Approximately 46% of existing capacity for storage of low-level solid waste required	No impact
Natural Environment			
Air Quality	Slight increases in PM ₁₀ emissions and emissions from construction and worker vehicles. No impact on air basin attainment.	Slight increases in PM ₁₀ emissions and emissions from construction and worker vehicles. No impact on air basin attainment.	No impact
Biological Resources	Up to 1,000 Joshua trees impacted by construction; temporary impacts to wildlife during operations due to noise; no impact to sensitive habitats or threatened and endangered species; loss of 100 acres of vegetation; possible loss of birds in flare stack	Temporary impacts to wildlife during operations due to noise; no impact to sensitive habitats or threatened and endangered species; loss of less than 50 acres of previously disturbed vegetation; possible loss of birds in flare stack.	No impact
Cultural Resources	No adverse impacts	No adverse impacts to potentially significant historic resources (CTF) if mitigations identified by consultation process are implemented.	No impact
Geology & Soils	26,000 cubic yards of cut, 37,000 cubic yards of fill; new construction required to meet standards for Seismic Zone IV	4,000 cubic yards of cut and 4,000 cubic yards of fill. New construction required to meet standards for Seismic Zone II.	No impact
Noise	Temporary impacts to wildlife during operations; 390 acres exposed to 60 dBA or greater	Temporary impacts to wildlife during operations; 390 acres exposed to 60 dBA or greater	No impact
Water Resources	No impact on water table or water quality	No impact on water table or water quality	No impact
Health and Safety*			
Maximum Yearly Release	0.14% of natural dose	0.31% of natural dose	No impact
Total Lifetime Dose	0.06% of natural dose	0.13% of natural dose	No impact
Maximum Case Accident	5.6% of natural dose**	6.8% of natural dose**	No impact

* Exposures are shown for a maximally exposed individual; average exposures would be much less.

** Assumes no evacuations and no mitigation measures.

Chapter 3



3.0 AFFECTED ENVIRONMENT

3.1 INTRODUCTION

This chapter describes environmental conditions at the two alternative locations for Space Nuclear Thermal Propulsion (SNTP) program activities: the Saddle Mountain Test Station (SMTS) and the Contained Test Facility (CTF), including the region of influence at each location. Information is provided to serve as a baseline from which to identify and evaluate environmental changes resulting from the Proposed Action or alternatives. Although this Environmental Impact Statement (EIS) focuses on the biophysical environment, some non-biophysical elements such as land use, public utility systems, and transportation networks in the region are addressed. This chapter also describes the storage, use, and management of hazardous materials. Finally, the pertinent natural resources of air quality, biological resources, cultural resources, geology and soils, noise, water resources, and health and safety are described.

Regions of influence will be defined for each affected resource and will determine the geographical area to be addressed as the affected environment. The region of influence assigns boundaries that reflect the true geographical limit of the specific resource, defines areas that encompass all potential impacts, provides context to allow regional analyses, where appropriate, and uses comparable study units when utilizing existing data bases. Although the direct project area constitutes the region of influence limit for most resources, potential impacts associated with certain issues (e.g. air quality, transportation, and water resources) transcend these limits.

Baseline conditions assumed for the purpose of analysis are the conditions as they currently exist. Impacts associated with potential program activities may then be addressed by comparing projected conditions to existing conditions.

3.1.1 Local Community

3.1.1.1 SMTS. The SMTS is located near the geographic center of the Nevada Test Site (NTS), about 75 miles northwest of Las Vegas, and lies in Mid Valley, a basin located east of Shoshone Mountain (see Figure 2.3-2). The NTS is in southern Nye County, Nevada (see Figure 2.3-1). The NTS contains 861,000 acres of federally owned land with restricted access, and is bordered on three sides by the Nellis Air Force Range (2,636,800 acres), another federally operated restricted area (Department of Energy (DOE), 1990a).

The region of influence for population is defined as Nye County and Clark County, Nevada, to include the main population center for Clark County, Las Vegas. Nye County is comprised of mostly rural areas, with small communities separated by great distances. The total population according to 1990 census data for the two-county region of influence is 759,240.

The region of influence for employment is defined as the NTS. Total employment at the NTS is approximately 5,000, which includes government and contractor personnel.

The NTS has been the primary location for the testing of nuclear devices in the United States since 1951. Historic testing at NTS includes atmospheric testing in the 1950s and early 1960s, earth-cratering experiments, and open-air nuclear reactor engine testing. Since 1963, all nuclear weapons tests have been carried out underground because of the atmospheric test ban treaty.

The NTS, in addition to its primary mission as the site for the nation's nuclear weapons test program, also was the principal location for ground based testing of nuclear rocket engines in the 1960s and early 1970s. Other tests of reactors, such as the Super Kukla, have been conducted at the NTS. From 1959 to 1973, the Nevada Research and Development Area (NRDA) conducted full-scale tests on over twenty reactors, including Kiwi, Peewee, Phoebus, Tory, NRX, and XE, which were being tested as possible propulsion systems for manned exploration of deep space. The NRDA was incorporated into the NTS in 1974.

In addition to the above tests, the Bare Reactor Experiment - Nevada was also conducted on a 1,527-foot tall tower located in Area 4. The tower is now located in Area 25 of the NTS. The tower was originally constructed for joint United States/Japanese Atomic Bomb Casualty Commission studies to determine the approximate exposure experienced by the survivors of the Hiroshima and Nagasaki bombings. The tower contained an unshielded reactor on an outside elevator to determine dose by distance and shielding measurements on target Japanese-type housing. Recently, the tower has been used for weather and sonic boom research and for conducting tests related to gravity.

Presently the NTS is the site of the Liquified Gaseous Fuels Spill Test Facility located on Frenchman Flat, which was completed in 1986. This facility was constructed for the purpose of conducting tests directed at understanding the physics of spill dispersion, minimizing spill effects, and cleanup technology and procedures.

Area 5 is the site of the low-level Radioactive Waste Management Site where defense waste from various sites across the nation are disposed of. Area 25 is the main support area for the Yucca Mountain Project Office at

the NTS. This organization is responsible for the studies to characterize Yucca Mountain for its suitability as a site for the storage of civilian radioactive waste in a deep underground repository. This site straddles 41 square miles of the NTS, the Nellis Air Force Gunnery Range, and land controlled by the U.S. Department of Interior, Bureau of Land Management.

3.1.1.2 CTF. The CTF is located in the northern portion of the Idaho National Engineering Laboratory (INEL) (see Figure 2.3-3) on the western edge of the Birch Creek Playa. The INEL comprises portions of Jefferson, Bingham, and Butte Counties, Idaho, and contains 580,000 acres of federally owned land with restricted access.

The region of influence for population is defined as the portions of 6 counties, Bannock, Bingham, Bonneville, Butte, Jefferson, and Madison, which lie within a 50 mile radius of the CTF, to include the major population center of the area, Idaho Falls. Total 1992 estimated population within the region of influence is 146,827.

The region of influence for employment is defined as the INEL. Total employment at the INEL is 11,600, which includes government and contractor personnel.

INEL was established by the federal government in 1949 to conduct research and further the development of nuclear reactors and related equipment. Major DOE programs at INEL include test irradiation services, uranium recovery from highly enriched spent fuels, calcination of liquid radioactive waste solutions, light-water-cooled reactor safety testing and research, operation of research reactors, environmental restoration, and storage and surveillance of transuranic wastes (DOE, 1991a). More than 50 reactors have been built at the INEL, of which 14 are still in active status. Major facilities at the INEL are operated by Argonne National Laboratory-West (ANL-W), EG&G Idaho, Babcock and Wilcox - INEL, Westinghouse Electric Corporation, and Westinghouse Idaho Nuclear Company.

The CTF is part of the Test Area North (TAN) complex located in the northern portion of INEL (see Figure 2.3-4). TAN was originally established in the 1950s to support the U.S. Air Force and Atomic Energy Commission Aircraft Nuclear Propulsion Program; however, the program was terminated before a nuclear-powered aircraft could be built. Facilities at TAN include an Initial Engine Test Facility, a Technical Support Facility, a Water Reactor Research Facility, and the CTF. A four-rail railroad track connects the Initial Engine Test Facility and CTF areas to the Technical Support Facility.

3.2 INFRASTRUCTURE

Infrastructure includes sources and supplies of electricity, solid waste disposal, wastewater disposal, and water. The region of influence for each component of infrastructure is the source that would supply the utility to each alternative site, as well as the system used to connect the source to the alternative site.

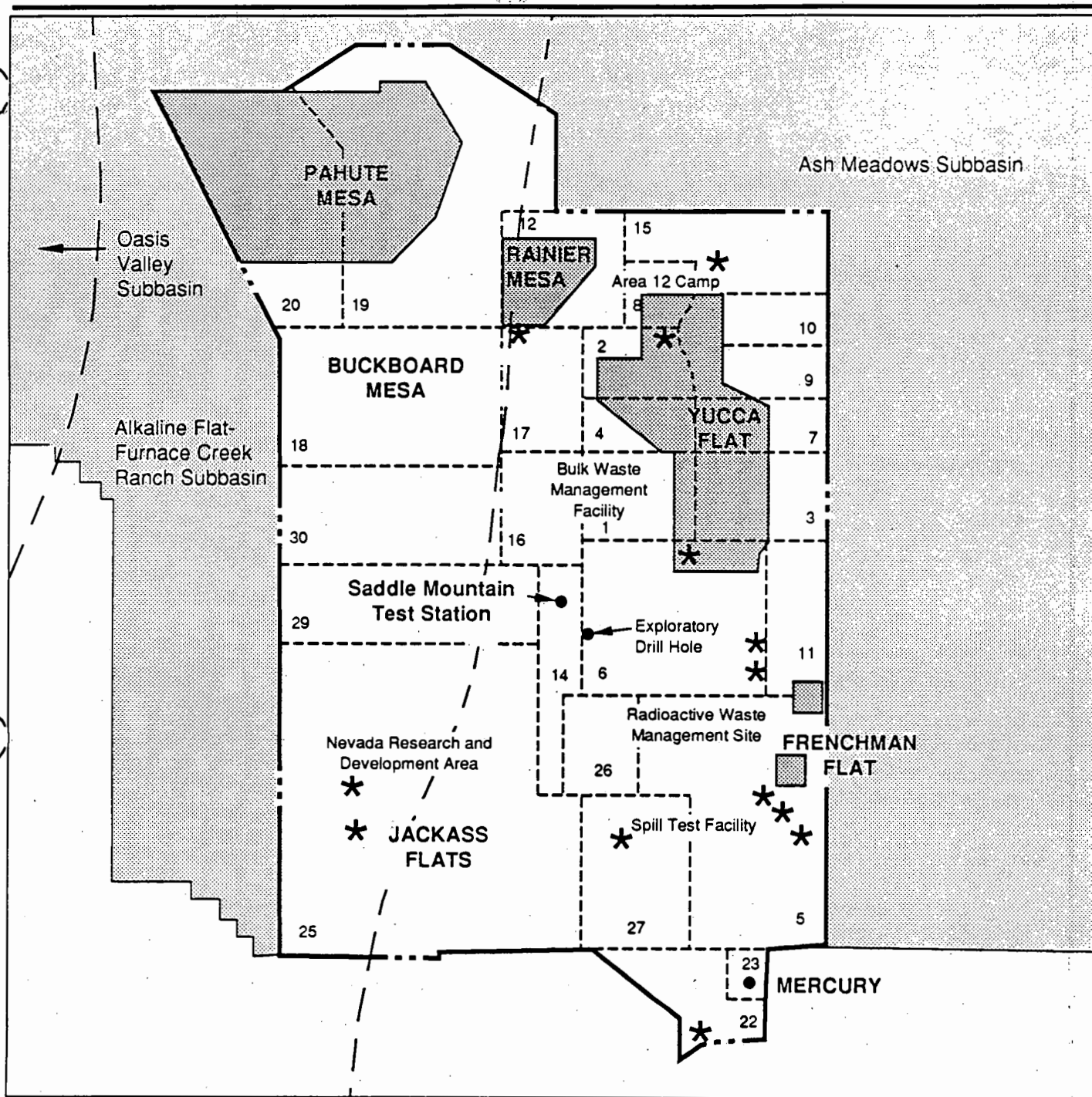
3.2.1 SMTS

3.2.1.1 Energy. The NTS uses commercial power provided by the Nevada Power Company over a 55 megawatt (MW) line rated at 138 kilovolts (kV). This line is 25 years old and in fair to good condition with minimal outages. Transmission and distribution systems with sufficient capacity to handle existing energy requirements are in place throughout the NTS Complex and closely parallel the road network on the NTS. There is no distribution line to the SMTS. An existing distribution line located 2.4 miles to the north has a capacity of 1.5 MW.

3.2.1.2 Solid Waste. Eight landfills are available for the disposal of nonradioactive, nonhazardous solid wastes. No state or U.S. Environmental Protection Agency (EPA) regulatory permits are required for these landfills. The NTS disposal sites include construction and sanitary landfills or trenches in Areas 3, 6, 20, 23, and 25, and a subsidence crater used as a landfill in Area 10. These landfills, with the exception of the subsidence crater, contain municipal and construction waste only. The subsidence crater is used for construction wastes including oil, stained soils, dirt, sewage sludge, aerosol cans, and asbestos. The landfills in Areas 3, 10, and 23 are anticipated to be operational for an additional 10 years. The landfills in Areas 20 and 25 are anticipated to be operational for an additional 5 years. The landfill in Area 6 has approximately 4 years of site life still available. Landfills in Areas 3, 6, 20, and 25 are temporarily closed. Other landfills in Areas 3 and 20 are used for drilling mud disposal. There are no active solid waste collection points at the SMTS. Landfills near SMTS are located in Areas 3, 6, and 25.

3.2.1.3 Wastewater. Wastewater at NTS is treated by various means ranging from treatment plants with primary and secondary capabilities to on-site septic systems. No sanitary treatment facilities currently exist at SMTS.

3.2.1.4 Water Supply. Groundwater is the only local source of water at the NTS. Drinking and industrial water for the NTS are produced from supply wells tapping four aquifers. Eleven NTS wells currently withdraw water from the Ash Meadows subbasin and two from the Alkaline Flat-Furnace Creek Ranch Subbasin for construction, drilling, fire protection, and consumption uses totaling 695 million gallons per year (Figure 3.2-1).



EXPLANATION

	Nuclear Testing Area		Nevada Test Site Boundary
	Nellis Air Force Range		Groundwater Subbasin Boundary
	Area Boundary		Water Well

Nevada Test Site

Water Well Locations

Figure 3.2-1

Permitting of these wells is not required under state water laws; however, the water system has several permits in place from the state of Nevada which require monthly bacteria sampling. Data collected from wells located in Areas 2, 5, and 6 of the NTS indicate that there has been no detectable decline in static water level and, therefore, consumption does not exceed yield for the Ash Meadow subbasin. Total withdrawals from two of these wells (C and C-1) in Area 6 average 0.07 million gallons per day (MGD). Wells in Areas 5, 6, and 25 supply approximately 0.86 MGD of groundwater to NTS facilities. The nearest water source to the SMTS is an existing 3,680 foot deep, large-diameter exploratory drill hole located near the axis of Mid-Valley, approximately 2.1 miles southeast of the SMTS (see Figure 3.2-1). This source is not currently used for water supply purposes.

3.2.2 CTF

3.2.2.1 Energy. Power service to the INEL is provided by an extensive electrical transmission/distribution system composed of 56.5 miles of 138 kV transmission line, 122.6 megavolt amperes (MVA) of transformer capacity, and seven major substations. INEL currently uses approximately 40 MVA for heating and power. Power supplied to the INEL is received from two sources: the Idaho Power Company and the on-site Experimental Breeder Reactor II, operated by ANL-W. The INEL has a 10-year contract with the Idaho Power Company for electrical energy, which expires in October 1996. It allows for an increase of power up to 55 MW with advance notice. Approximately 60 percent of the power required for site operations is provided from the Idaho Power Company, with the remainder generated on site by the Experimental Breeder Reactor-II. The CTF receives electricity from the Idaho Power Company. The capacity of existing transformers at TAN, which also supply CTF, is 120 MW. Existing demand for these sites is 30 MW.

3.2.2.2 Solid Waste. Municipal and construction solid waste generated at the CTF is disposed at the Central Facilities Area landfill. The Central Facilities Area landfill, permitted by the state of Idaho, is anticipated to be operational until 1995 when a new landfill site will be completed and ready for operation.

3.2.2.3 Wastewater. Nonradioactive, nonhazardous liquid effluent streams are discharged into percolation ponds, evaporation ponds, or sewage treatment facilities, depending on the nature of the wastewater. The wastewater system used at the CTF includes a 4,000-gallon septic tank connected to a 16 million gallon lagoon. The facilities are permitted by the state of Idaho. No National Pollution Discharge Elimination System permits are required.

3.2.2.4 Water Supply. Water wells at INEL tap the Snake River Aquifer, which contains an estimated one billion acre feet of water. INEL is

permitted to pump 52 MGD from 27 existing production wells and currently pumps up to 6 MGD depending on facility needs (Figure 3.2-2).

The CTF existing water systems provide a source of water for the CTF integral test system, storage, pumping, distribution piping for fire protection purposes, and a source of water for interfacing systems such as service water and domestic water. The domestic water system at CTF supplies the demand for hot and cold water for showers, lavatories, sinks, and other fixtures. The service water system supplies water for cooling heat exchangers, softened and demineralized water systems, pump seals to prevent outleakage of fluids, and various washing and flushing operations.

Water pumping and storage facilities, located approximately 1,200 feet east of the main CTF area, consist of the following:

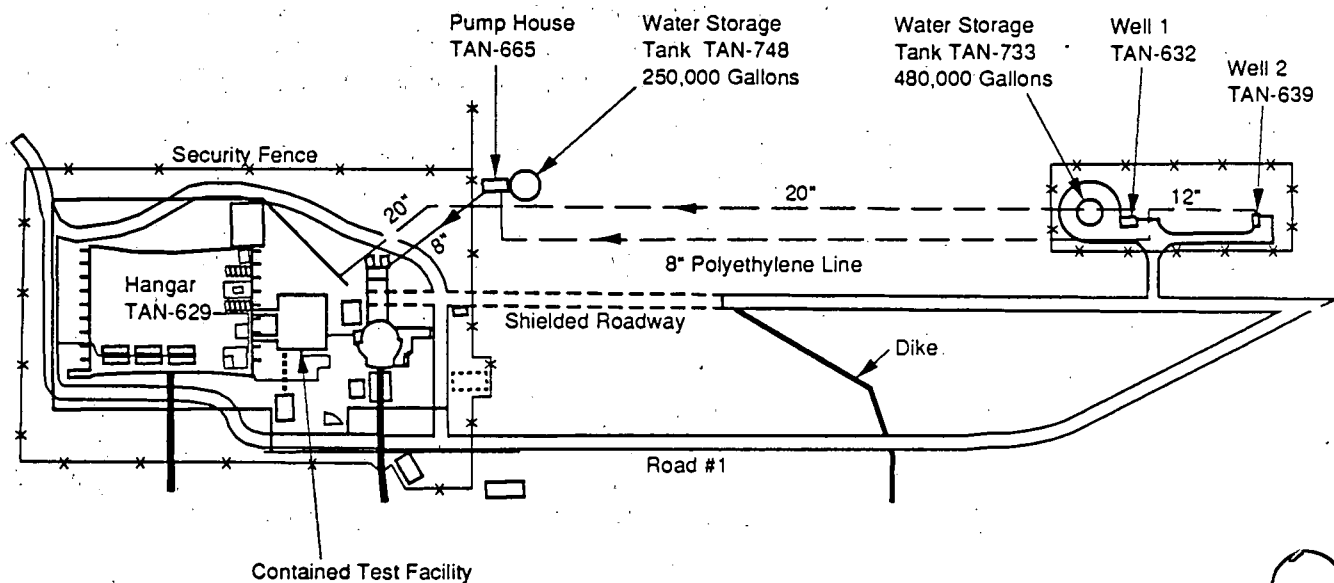
- Two pumphouses (TAN-632 at Well Number 1 and TAN-639 at Well Number 2) each with one pump with pumping capacity of 1,000 gallons per minute (1.44 MGD). The water table is approximately 200 feet deep; the wells are 340 feet and 461 feet deep. Each has been tested to discharge flows up to 3,000 gallons per minute (4.32 MGD). The system can be aligned for the well pumps to discharge into a 480,000 gallon storage tank next to Well Number 1 or a 250,000 gallon storage tank northeast of the CTF (described below).
- A water storage tank and pumphouse were installed in 1980, approximately 350 feet northeast of the CTF reactor area, to provide a redundant supply. The tank can store 250,000 gallons. A diesel-powered pump, rated at 1,500 gallons per minute (2.16 MGD), discharges directly into the fire hydrant piping system that surrounds the CTF area. It can supply water for fire protection, domestic, and service water demands.

3.3 LAND USE

The land use resource for this program considers whether the current and projected land use at the alternative sites is compatible with implementation of the Proposed Action. The region of influence for this resource is the immediate vicinity of the alternative sites. To provide context, the general land uses of the two installations are also described.

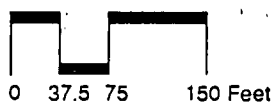
3.3.1 SMTS

Land within NTS is used exclusively for national defense and energy-related purposes by DOE and is not open to public use for any purposes, including agriculture, mining, homesteading, or recreation. The principal land use areas of NTS are shown in Figure 3.3-1. The installation is separated into



EXPLANATION

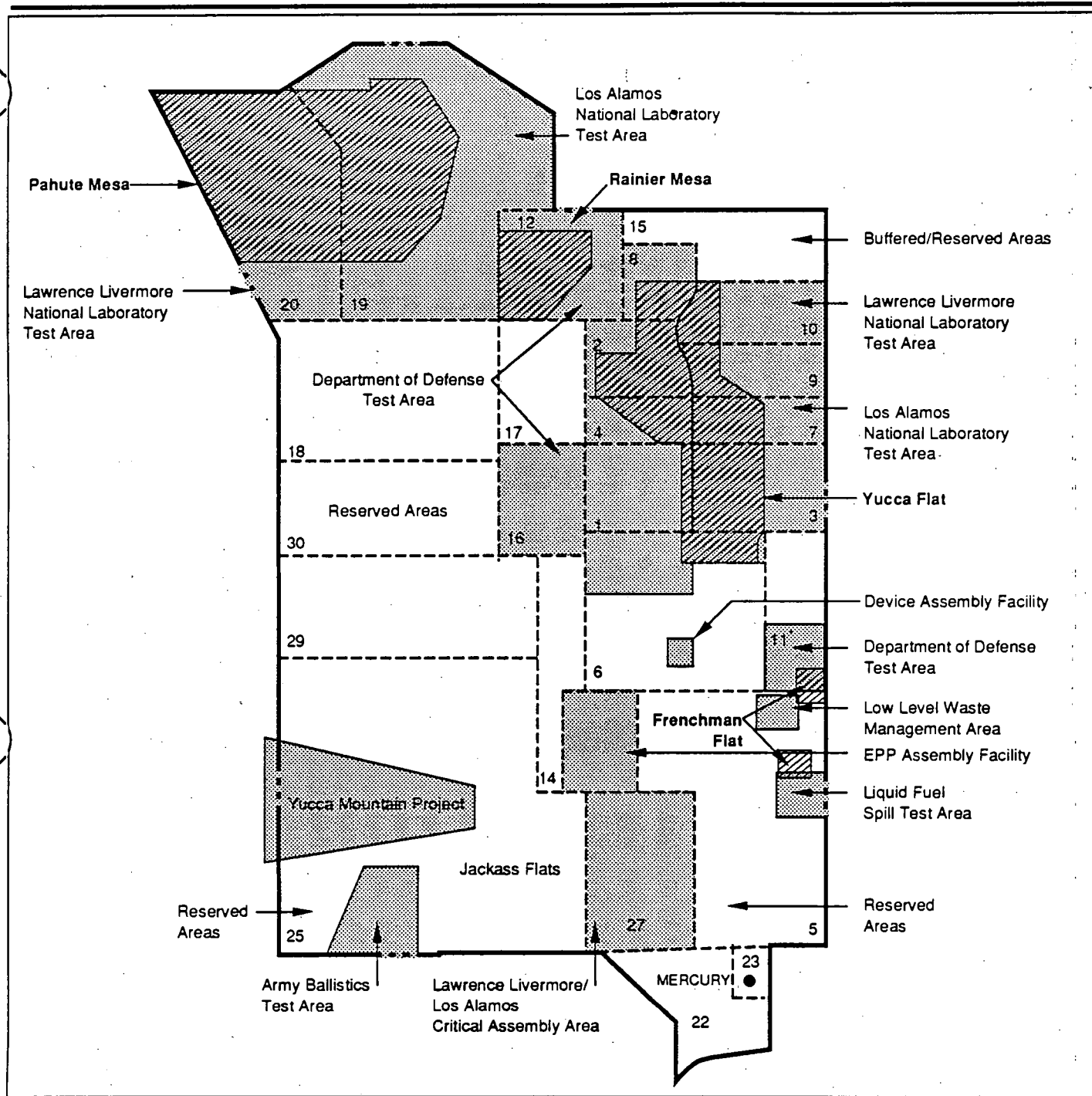
--- Raw Water
--- Fire Water



Idaho National
Engineering
Laboratory

Water Wells
at CTF

Figure 3.2-2



EXPLANATION

- Nevada Test Site Boundary
- Area Boundary
- Area Assigned to Designated User
- Nuclear Weapons Testing Areas



Nevada Test Site

Land Use Areas and Existing Designated Land Users

Figure 3.3-1

land areas dedicated to nuclear research and development, testing and development of nuclear weapons, studies to determine effects of radioactivity, disposal of low-level waste, and logistics support for nuclear research and development projects. Nuclear testing activities at the NTS have included atmospheric and underground tests of nuclear explosives in Areas 2, 3, 4, 5, 7, 9, 10, 12, 19, and 20. At present, tests are conducted at Yucca Flat, Rainier Mesa, and Pahute Mesa. Testing of nuclear reactors, nuclear engines, and nuclear furnaces have been conducted at the Nevada Research and Development Area located in Jackass Flats.

Area 5 contains the Radioactive Waste Management Site (RWMS) for the storage of low-level waste generated by several DOE facilities. A full range of site support activities are located in Area 6, the central control point for nuclear test operations, Area 12, the northern camp area, and Area 23 (Mercury) on the southern end of the site. Billeting is available at Mercury and the Area 12 camp.

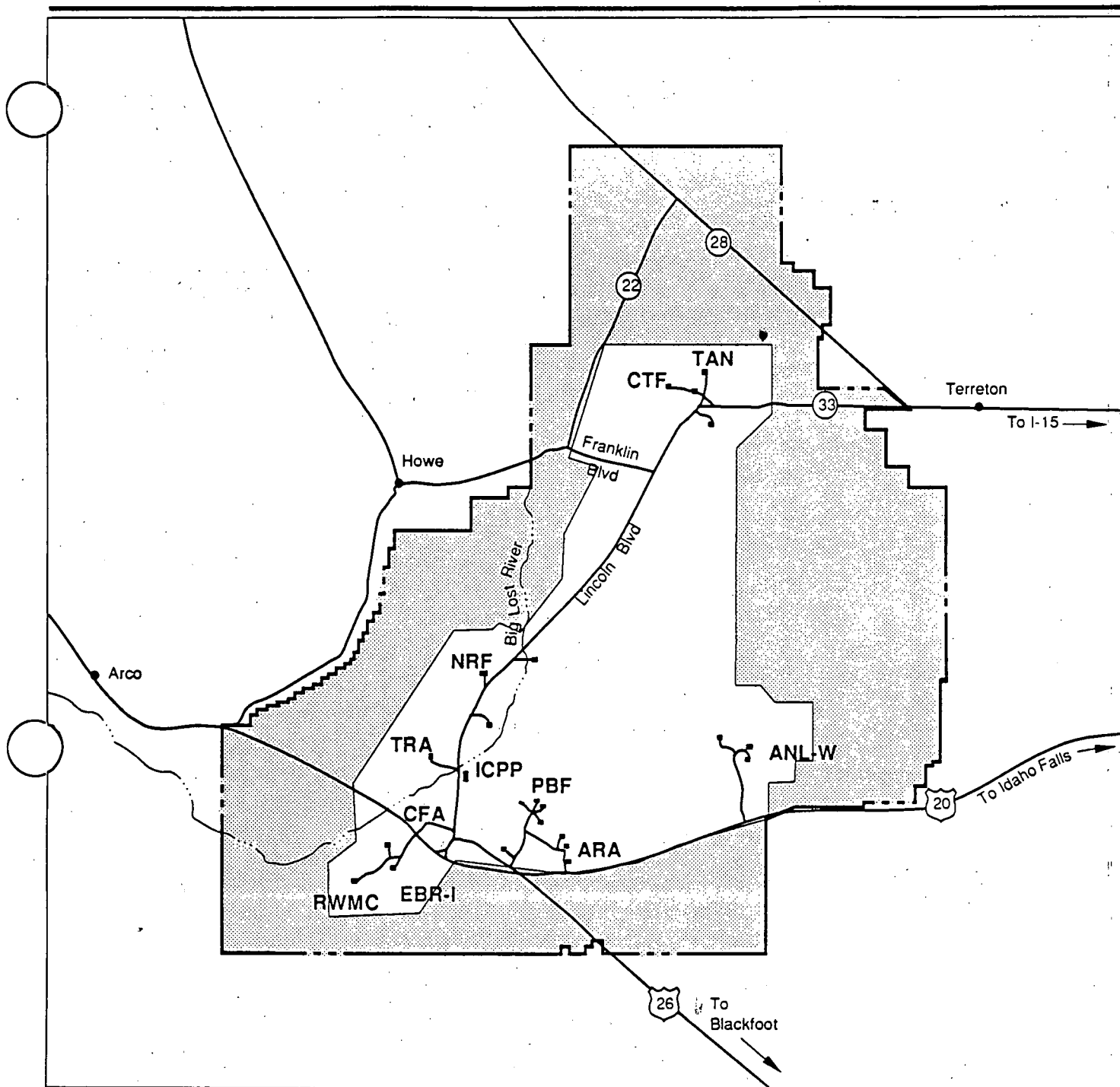
A small portion of Area 14 approximately 3 miles north of the SMTS was previously used for solid propellant testing. The SMTS site is undeveloped and is reached by unimproved dirt roads.

3.3.2 CTF

INEL operates as a DOE multi-program installation. The primary function of INEL is to conduct research on nuclear reactors and related equipment. Unlike NTS, INEL does not categorize the land uses on the installation by functional area. There are two distinct land uses on INEL: research and development, and grazing area (Figure 3.3-2). Within the research and development land use, 11 facilities/areas are dedicated to specific programs. Each facility is separated by large open spaces that provide appropriate buffer and safety zones between the facilities. The grazing area has been established by DOE permit as a safety buffer between the test areas and public lands. INEL maintains the authority to restrict grazing activities during operational activities.

The facility site areas (see Figure 3.3-2) contain programs that support the INEL function; examples of facilities/activities are ship propulsion reactors and training facilities, materials testing, breeder reactor research and development, and disposal of radioactive waste.

The CTF site was originally constructed as an operational test facility, and is functionally part of the TAN complex. The CTF site represents less than 0.01 percent of the total land area of the INEL (see Figure 3.3-2). Facility structures include the Containment and Service Building, an aircraft hangar, the Control and Equipment Building, and other support facilities. A specially designed railroad flatcar is available to transport mobile reactor assemblies into and out of the containment vessel. Systems for operating and



EXPLANATION

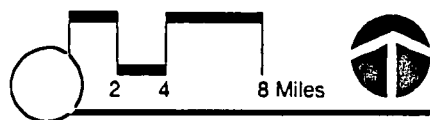
-  Research and Development
-  Grazing Area
-  NTS Boundary

- ANL-W - Argonne National Laboratory West
- ARA - Auxiliary Reactor Area
- CFA - Central Facility Area
- CTF - Contained Test Facility
- EBR-I - Experimental Breeder Reactor-I
- ICPP - Idaho Chemical Processing Plant
- NRF - Naval Reactors Facility
- PBF - Power Burst Facility
- RWMC - Radioactive Waste Management Complex
- TAN - Test Area North
- TRA - Test Reactor Area

Idaho National Engineering Laboratory

Principal Land Use Areas

Figure 3.3-2



monitoring the reactor are located inside structures immediately adjacent to the containment vessel. The CTF is currently undergoing asbestos abatement.

3.4 TRANSPORTATION

Transportation includes those aspects of roadways that would be used by program employees and to support operational requirements at the alternative sites and includes airspace considerations at the alternative sites. The region of influence for roads is the installation road network as well as major roads connecting the installation with nearby communities; the region of influence for airspace for the SMTS is the NTS and adjoining Nellis Range, and for the CTF is INEL.

3.4.1 SMTS

3.4.1.1 Transportation. Access to the SMTS is provided by unpaved, gravel roads (see Figure 2.3-2). Mid Valley Road, connecting SMTS with Pahute Mesa Road to the north and with Cane Springs Road to the south, is a narrow gravel road. Mine Mountain Road to the east of the SMTS is a two-lane gravel road providing access to Mercury Highway. Saddle Mountain Road is a two-lane gravel road to the south of the SMTS, providing access from Lathrop Wells Road and the Nevada Research and Development Area. During underground testing, both Mine Mountain Road and Saddle Mountain Road may be blocked for access.

Access to the NTS is controlled at all times. The access for all construction materials would be via U.S. 95 and the Mercury Highway. Mercury Highway is a paved, two-lane road that runs north-south on the east side of the site, connecting to U.S. 95 at the southeastern end of the NTS. Mercury Highway is used by the majority of traffic travelling to existing test sites and support sites, with the primary access gate to the NTS located approximately one mile north of the junction with U.S. 95. A second access point on Mercury Highway, located in the northeastern corner of the NTS, can be reached from State Route 375, approximately 21 miles northeast of the NTS boundary. Lathrop Wells Road on the southwest corner of the NTS provides access from U.S. 95.

U.S. 95 and the Mercury Highway is the only public access to the NTS. From Las Vegas to the junction with Mercury Highway, U.S. 95 is a four-lane, divided highway, with an annual average daily traffic (AADT) volume of 3,400 vehicles. Peak hour (6:30 a.m. to 8:00 a.m. and 4:30 p.m. to 6:30 p.m.) traffic volume at the Mercury Highway Junction 13 is approximately 550 vehicles. West of the Mercury Highway Junction, U.S. 95 is reduced to two lanes, and has an average traffic volume of 2,535 AADT.

Approximately 5,000 commuting employees use their private automobiles, travel in car pools, or ride in chartered buses to and from work. Approximately 100 buses operate from Las Vegas to the NTS on a daily basis.

3.4.1.2 Airspace. The airspace overlying the NTS and the adjoining Nellis Range is referred to as the Nellis Range Complex. All the airspace within the complex is restricted airspace. This restricted area is set aside by the Federal Aviation Administration to accommodate activity that presents a hazard to non-participating aircraft, either military or civilian. These areas within the Nellis Complex are designated geographically and vertically to ensure safe separation of aircraft. Also, the air traffic control of the ranges is provided by Nellis Air Force Base in coordination with DOE at NTS.

3.4.2 CTF

3.4.2.1 Transportation. Ninety miles of paved U.S. and state highways cross through INEL (see Figure 2.3-4). U.S. 20 and 26 pass through the southern portion of INEL. Average traffic volume on U.S. 20 at the junction with U.S. 26 is 2,290 AADT, with peak hour traffic of 400 to 450 vehicles. Average traffic volume on U.S. 26 at this junction is 1,050 AADT. State Highways 22, 28, and 33 pass through the northern portion of INEL. These highways are open to the public. Access to the interior portions of the INEL facilities is controlled at check points manned by security guards.

The CTF is located at the end of Snake Avenue in the Northern portion of INEL, approximately two miles from the intersection of Lincoln Boulevard and State Route 33. State Route 33 connects with Interstate 15 approximately 25 miles north of Idaho Falls. Average traffic volume on Highway 33 at the intersection of Highway 28 is 530 AADT. Lincoln Boulevard, which is not open to the public, is the main road that connects the CTF to the southern portion of INEL, and to U.S. 20. The distance from the CTF to U.S. 20 is approximately 28 miles.

Commuting employees are transported from their communities to INEL by 131 passenger buses. These buses transport 4,000 to 5,000 employees daily and run on regular schedules from the surrounding communities of Arco, Pocatello, Blackfoot, Idaho Falls, Rigby, Rexburg, Shelley, and Mackay.

Currently, the INEL occasionally requires the closure of public roads to transport high activity or large size loads from site to site. A typical example was the transportation of a large irradiated materials shipment cask that required the closure of 17 miles of U.S. 20 in order to safely move it from the Test Reactor Area to ANL-W during the mid-1970s to early 1980s. Closures of public roads in these instances are negotiated with the state of Idaho and closure plans implemented. For large cask shipments, approval of

the State of Idaho Transportation Department was obtained in the transportation plan document and in the obtaining of an oversize load permit.

3.4.2.2 Airspace. The airspace around INEL is designated by Federal Aviation Regulation as a National Security Area. Flights below 6,400 feet mean sea level (MSL) are prohibited. The elevation of the CTF is approximately 4,800 feet MSL. Therefore, no aircraft will be closer to the ground than approximately 1,600 feet.

3.5 HAZARDOUS MATERIALS AND HAZARDOUS WASTE MANAGEMENT

Hazardous materials and hazardous waste management activities at both SMTS and CTF are governed by specific environmental regulations. For the purpose of the following analysis, the terms hazardous waste and hazardous materials mean those substances defined as hazardous by the Comprehensive Environmental Response Compensation and Liability Act, 42 U.S. Code (USC) §9601-9675, as amended, and the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA), 42 USC §6901-6992, as amended. In general, this includes substances that, because of their quantity, concentration, or physical, chemical, or infectious characteristics, may present substantial danger to public health or welfare or the environment when released.

Transportation of hazardous materials is regulated by Department of Transportation regulations within Chapter 49 of the Code of Federal Regulations (CFR). In the states of Nevada and Idaho these regulations are not supplemented by state statute or regulation.

All fuel fabrication and fuel assembly operations would be performed at Babcock and Wilcox (B&W) Naval Nuclear Fuel Division in Lynchburg, Virginia. B&W would package these PBR fuel elements into a criticality safe configuration and provide a shipping container suitable for over-the-road shipments. DOE would assume accountability for the nuclear fuel material at the point of fabrication and provide safe, secure transportation to the proposed testing location.

Radioactive hazardous materials expected to be generated by PBR validation test facility activities include low-level waste (LLW), mixed waste, and, potentially, transuranic (TRU) waste. LLW consists of all radioactive waste not classified as high-level waste, spent nuclear fuel, TRU waste, uranium mill tailings, or mixed waste. LLW can contain TRU nuclides (those having an atomic number greater than 92) in concentrations not greater than 100 nanocuries per gram. Mixed waste is waste containing both radioactive components and nonradioactive hazardous components as defined by the Atomic Energy Act and RCRA, respectively. TRU waste is radioactive waste containing alpha-emitting radionuclides having an atomic number greater

than 92 and half-lives greater than 20 years in concentrations greater than 100 nanocuries per gram.

Treatment and disposal of nonhazardous waste, including wastewater, is discussed in Section 3.2, as part of infrastructure support.

The regions of influence for management of hazardous materials or hazardous wastes from SMTS and CTF are the NTS and INEL, respectively, since site-wide programs are currently in place.

3.5.1 SMTS

3.5.1.1 Hazardous Materials Management. Hazardous materials at the NTS are controlled and managed from the point of purchase through disposal by hazardous material accountability systems. The NTS currently has a permit for generation of polychlorinated biphenyls and a hazardous chemicals permit for controlled releases (Area 5). No hazardous materials are known to be present at the SMTS site due to the undeveloped nature of the area.

3.5.1.2 Nonradioactive Hazardous Waste. Hazardous wastes generated at the NTS are managed in accordance with the provisions of RCRA. Department of Energy, Nevada field office (DOE/NV) reports all RCRA generator activities under its identification number NV 389 009001 (DOE, 1990d). Up to 55 gallons of these wastes are collected at local testing facilities and are then transferred to the Area 5 Hazardous Waste Accumulation Pad. Within 90 days of arrival at the Hazardous Waste Accumulation Pad the wastes are sent for ultimate disposal at an EPA-approved off-site treatment, storage or disposal facility. Approximately 3,500 cubic feet of hazardous waste are generated from NTS activities each year.

Because the area is undeveloped, no hazardous waste is being generated at the SMTS site.

3.5.1.3 Radioactive Hazardous Waste. Existing waste handling facilities at NTS are located at the RWMS in Area 5 and the Bulk Waste Management Facility (BWMF) in Area 3. The RWMS is used for LLW disposal, mixed waste disposal, TRU storage, hazardous waste accumulation, and disposal of classified material. Bulk LLW is disposed at the BWMF.

Low-Level Radioactive Solid Waste

The estimated remaining capacity for solid LLW at the NTS is approximately 17.7 million cubic feet (20 years) with an estimated annual input of 880,000 cubic feet (DOE/NV, 1990c). There is no existing capacity for liquid LLW (DOE/NV, 1990c).

Mixed Waste

To provide disposal capacity for mixed waste, the DOE/NV has obtained, from EPA, interim operating status for a Mixed Waste Management Unit (MWMU) at the RWMS. DOE/NV has applied for an RCRA Part B permit from the state of Nevada for disposal of mixed waste (DOE, 1990d). To date, approximately 200,000 cubic feet of mixed waste has been stored (DOE, 1990a). The MWMU is to be operable for five years from Part B permit issuance or until 5.3 million cubic feet of mixed waste has been accumulated, whichever comes first (DOE, 1990). The annual input of mixed waste to the MWMU is approximately 700,000 cubic feet.

TRU

TRU wastes (elements with atomic numbers higher than 92) are stored in a TRU storage pad at the RWMS in preparation for transfer to the Waste Isolation Pilot Plant (WIPP) in New Mexico when it opens. The current volume of TRU is approximately 21,000 cubic feet (DOE, 1990d); the estimated remaining capacity of the TRU storage pad is approximately 35,000 cubic feet (DOE/NV, 1990c).

3.5.1.4 Environmental Restoration. Environmental restoration activities currently proceeding at NTS include closure activities for steam cleaning effluent ponds and closure of the Decontamination Facility evaporation pond (Area 6); closure, temporary closure, or removal of underground storage tanks (Areas 12, 23, and 25); and disposal of wastes from NTS tunnels (Areas 5 and 12). The SMTS is not known to contain any hazardous waste sites due to its undeveloped nature.

3.5.2 CTF

3.5.2.1 Hazardous Materials Management. Hazardous materials at the INEL are controlled and managed from the point of purchase through disposal by hazardous material accountability systems at each facility. No hazardous materials are currently being utilized or generated at CTF.

3.5.2.2 Nonradioactive Hazardous Waste. More than 30 facilities at INEL generate RCRA-regulated hazardous waste. Hazardous waste is temporarily stored at the Hazardous Waste Shipping Facility which currently handles 590 cubic feet per year of hazardous waste prior to regular off-site shipment for final disposal at licensed RCRA facilities. Existing capacity of this shipping facility is approximately 6,500 cubic feet.

The Waste Reductions Operations Complex (WROC) manages all hazardous waste generated on INEL or shipped to INEL from other locations and includes a Hazardous Waste Storage Facility and Mixed Waste Storage Facility. The WROC receives, inspects, handles, temporarily stores, and

ships hazardous waste to approved on-site and off-site storage and disposal locations.

CTF activities are limited; therefore, hazardous waste is not currently being generated. Some removal of asbestos, including removal of asbestos gaskets, floor tile and mastic, ceiling tile, and pipe/duct insulation, is being accomplished with disposal to a permitted hazardous waste management facility for eventual permanent disposal.

3.5.2.3 Radioactive Hazardous Waste. The Radioactive Waste Management Complex (RWMC) is a storage and disposal facility intended primarily for radioactive materials from defense and nuclear energy research programs. The RWMC is located in the southwest corner of INEL (see Figure 3.3-2).

Low-Level Radioactive Solid Waste

Solid LLW is disposed in an active portion of the fenced Subsurface Disposal Area located in the western part of the RWMC. The Subsurface Disposal Area contains pits, trenches, and vaults excavated into the basalt. The total volume of waste disposed in the Subsurface Disposal Area is about 3.7 million cubic feet; about 11 million cubic feet of solid LLW is buried annually. An environmental monitoring program continuously evaluates impacts of current operations and is used to predict impact of proposed additions and/or modifications to the facility.

Mixed Waste

Mixed wastes are handled at the Radioactive Mixed Waste Storage Facility at RWMC. These wastes are stored on an interim basis until shipped to an off-site-approved EPA Treatment, Storage, or Disposal Facility.

TRU

TRU waste is packaged at the individual facilities that generate this waste, then kept in retrievable storage at the Transuranic (waste) Storage Area. The Transuranic Storage Area consists of asphalt storage pads for contact-handled TRU waste, each of which can store 1.4 million cubic feet of waste. Pads are constructed as required and sufficient room exists inside the current Transuranic Storage Area boundaries for 16 waste storage pads with a total storage capacity of 21 million cubic feet. As of 1988, 2.3 million cubic feet of TRU waste was stored at this facility. The TRU waste storage capacity is adequate to store INEL baseline projected waste volumes until shipment to the WIPP or another designated facility.

3.5.2.4 Environmental Restoration. In November 1989, the Secretary of Energy established the United States Department of Energy Office of

Environmental Restoration and Waste Management (EM) for the purpose of consolidating environmental restoration and waste management activities. The existing EM Program primarily resolves environmental restoration and waste management activities on a site-by-site basis.

The National Contingency Plan and Superfund Amendment and Reauthorization Act (SARA) of 1986 identify the procedures to be followed when addressing any hazardous waste sites. Since SARA was passed, most federal facilities have been placed on a federal docket and the EPA has been evaluating the facilities' waste sites for possible inclusion on the National Priorities List (NPL).

The INEL was placed on the NPL in 1989 to facilitate cleanup and monitoring of contaminated areas. An injection well located at TAN, in close proximity to the CTF, is one of the NPL contaminated sites. Disposal of liquid effluent generated by operations at TAN into a well between 1955 and 1972 resulted in small accumulations of two volatile organic compounds along with small amounts of low level radioactive contamination in the sediments. Concentrations of trichloroethylene at one point exceeded the EPA maximum contaminant level in drinking water. Removal of a 60-foot column of sediment in the former injection well was completed in 1990. An aeration system was installed to remove trichloroethylene from the water before it reaches the distribution system and the drinking water is monitored monthly to ensure that concentrations remain at safe levels.

3.6 AIR QUALITY

Air quality in a given location is described as the concentration of various pollutants in the atmosphere, generally expressed in parts per million or micrograms per cubic meter. Air quality is determined by the type and amount of pollutants emitted into the atmosphere, the size and topography of the air basin, and the prevailing meteorological conditions. The significance of a pollutant concentration is determined by comparing it to federal and/or state ambient air quality standards. These standards represent the maximum allowable atmospheric concentrations that may occur and still protect public health with a reasonable margin of safety. Federal standards are established by the EPA and are called National Ambient Air Quality Standards (NAAQS) (Table 3.6-1). The main pollutants considered in this analysis are ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter less than 10 microns in diameter (PM_{10}).

In general, the region of influence is the regional air quality basin within which the proposed site locations occur.

The Clean Air Act (CAA) requires that project emission sources comply with the air quality standards and regulations that have been established by

Table 3.6-1. National Ambient Air Quality Standards (NAAQS)

Pollutant	Primary (Health Related)		Secondary (Welfare Related)	
	Averaging Time	Standard Level Concentration ^(a)	Averaging Time	Standard Level Concentration
PM ₁₀	Annual Arithmetic Mean ^(b)	50 $\mu\text{g}/\text{m}^3$		Same as Primary
	24-hour ^(b)	150 $\mu\text{g}/\text{m}^3$		Same as Primary
SO ₂	Annual Arithmetic Mean	(0.03 ppm) 80 $\mu\text{g}/\text{m}^3$	3-hour ^(c)	1,300 $\mu\text{g}/\text{m}^3$ (0.50 ppm)
	24-hour ^(c)	(0.14 ppm) 365 $\mu\text{g}/\text{m}^3$		
CO	8-hour ^(c)	9 ppm (10 $\mu\text{g}/\text{m}^3$)		No Secondary Standard
	1-hour ^(c)	35 ppm (40 $\mu\text{g}/\text{m}^3$)		No Secondary Standard
NO ₂	Annual Arithmetic Mean	0.053 ppm (100 $\mu\text{g}/\text{m}^3$)		Same as Primary
O ₃	Maximum Daily 1-hour Average ^(d)	0.12 ppm (235 $\mu\text{g}/\text{m}^3$)		Same as Primary
Pb	Maximum Quarterly Average	1.5 $\mu\text{g}/\text{m}^3$		Same as Primary

Notes: (a) Parenthetical value is an approximately equivalent concentration.

(b) TSP was the indicator pollutant for the original particulate matter (PM) standards. This standard has been replaced with the new PM₁₀ standard and it is no longer in effect. New PM standards were promulgated in 1987, using PM₁₀ (particles less than 10 μ in diameter) as the new indicator pollutant. The annual standard is attained when the expected annual arithmetic mean concentration is less than or equal to 50 $\mu\text{g}/\text{m}^3$, the 24-hour standard is attained when the expected number of days per calendar year above 150 $\mu\text{g}/\text{m}^3$ is equal to or less than 1, as determined according to Appendix K of the PM NAAQS.

(c) Not to be exceeded more than once per year.

(d) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1, as determined according to Appendix H of the Ozone NAAQS.

$\mu\text{g}/\text{m}^3$ = micrograms per cubic meter

ppm = parts per million

federal, state, and local regulatory agencies. Standards and regulations focus on (1) the maximum allowable ambient pollutant concentrations resulting from project emissions, both separately and combined with other surrounding sources, and (2) the maximum allowable emissions from the project. According to EPA requirements, an area with air quality better than the NAAQS is designated as being in attainment; areas with worse air quality are classified as nonattainment areas. A nonattainment designation is given to a region if the primary NAAQS for any criteria pollutant is exceeded at any point in the region; the state may also designate areas as either in attainment or nonattainment.

The Prevention of Significant Deterioration (PSD) program (CAA Subchapter 1 Part C Sections 160-169) requires an owner or operator to obtain a permit before construction of a major new source or major modification of certain existing sources located in an attainment or unclassified area. A major stationary source, as defined by the PSD regulations, is any source belonging to a list of 28 specified categories that has the potential to emit 100 tons per year or more of any pollutant regulated under the CAA. Potential to emit is based on the maximum design capacity of a source and takes into account pollution control efficiency. Sources not on the list of 28 categories are considered major if they have potential emissions of 250 tons per year or more of any pollutant regulated under the CAA. Once an existing source is considered major, PSD review is required if the modification to the source results in a net increase in pollutants in significant amounts.

Under the PSD, increments and ceilings have been established for areas (known as Class I, II, or III areas) throughout the United States. Class I areas have been identified primarily to monitor and protect air quality near certain national parks, wilderness areas and monuments. Class II areas encompass the rest of the nation. Class III areas allow a larger incremental increase of pollutants than Class I or II. No Class III areas have been designated at this time.

Airborne radiation is regulated by the National Emissions Standards for Hazardous Air Pollutants and is discussed in Section 3.12.

3.6.1 SMTS

The NTS is located within Nevada Intrastate Air Quality Control Region 147 and, in accordance with national and state of Nevada air quality standards, is in attainment for all criteria pollutants. The NTS is designated as a Class II air quality region. There are PSD monitoring requirements for the installation. The nearest nonattainment area is Las Vegas, which does not meet the NAAQS for CO and PM₁₀.

The NTS has a desert climate characterized by cool winters, hot summers, low rainfall (approximately four inches per year), and, generally, predictable wind patterns. Predominant winds are northwesterly in winter, southwesterly in summer, and westerly in spring and fall; daily variations are typically southwesterly in early afternoon and northerly from sundown to midday. The topography of the NTS is conducive to good air dispersion.

Air Pollution Emission Sources

Air pollution sources found within the NTS area include aggregate production, surface disturbances, fugitive dust from unpaved roads, fuel burning equipment, open burning, and fuel storage facilities (DOE, 1990).

The NTS currently has 24 air quality operating permits and 16 permits to construct from the state of Nevada. These combined activities produce all NAAQS criteria pollutants in levels below NAAQS standards. No emission sources are found in the immediate vicinity of the SMTS.

3.6.2 CTF

The INEL is located within the Eastern Idaho Intrastate Air Quality Control Region and, in accordance with national and state of Idaho air quality standards, is in attainment for all criteria pollutants. A large portion of Craters of the Moon National Monument, which is located 42 miles southwest of the CTF, is designated as a Class I air quality region. The nearest non-attainment area is Pocatello, Idaho, 75 miles south of the CTF. Pocatello exceeds the NAAQS for PM₁₀.

The INEL is situated in a semi-arid region with warm summers and cold winters; average annual precipitation is 9 inches. The prevailing wind directions are from the southwest to west-southwest and from the north-northeast to northeast. The topography of the INEL is conducive to good dispersion.

Air Pollution Emission Sources

Air pollution sources found in the INEL area include the calcination of liquid waste, the combustion of coal for steam generation at the Idaho Chemical Processing Plant, and the combustion of fuel oil for heating at various INEL facilities. Other emissions include fugitive particulate emissions from waste-burial activities and coal piles, other process emissions, vehicular emissions, and temporary emissions from various construction activities. These combined activities produce all NAAQS criteria pollutants, but do not exceed the NAAQS. Air pollution emission permits for two major sources, following PSD regulation requirements (40 CFR Part 52), have been approved. PSD permits were obtained for a coal-fired, steam-generating plant next to the Idaho Chemical Processing Plant (DOE-24) and for the Fuel Processing Restoration Facility, both of which are located within the INEL (DOE, 1991).

3.7 BIOLOGICAL RESOURCES

Biological resources include the native and introduced plants and animals in the project area. For discussion purposes, biological resources are divided into vegetation, wildlife, threatened or endangered species, and sensitive habitats.

Sensitive habitats include wetlands, plant communities that are unusual or of limited distribution, and important seasonal use areas for wildlife (e.g., migration routes, breeding areas, or crucial summer/winter habitat).

The regions of influence for biological resources are the project site areas and associated areas potentially affected by construction for needed infrastructure (i.e., utility and road extensions or improvements). For the SMTS, the region of influence is approximately 100 acres; for the CTF site, which contains existing developed areas and infrastructure, the region of influence is 100 acres, including less than 50 acres of vegetation disturbed during previous activities at the site. To provide context, regional aspects of vegetation, wildlife, and threatened and endangered species are also discussed.

3.7.1 SMTS

3.7.1.1 Vegetation. The flora of the SMTS is typical of that of the Mid Valley area. Mid Valley is described as Transitional Desert Association, which extends in a broad east-west corridor between the Mojave and Great Basin deserts at elevations of between 4,000 and 5,000 feet MSL (DOE, 1986). Vegetation within this association consists predominantly of widely spaced clumps of low brush interspersed with sparse growths of grasses and other low plants and scattered Joshua trees and Mojave yucca (Sandia National Laboratories, 1990b; EG&G, 1992). Vegetative coverage of the soil surface is approximately 20 percent. Blackbrush is the predominant plant species (Table 3.7-1). Brush fires have resulted in modification of the vegetation of the area.

3.7.1.2 Wildlife. The southern Great Basin is occupied by a variety of birds, reptiles, and mammals representing faunal elements from both the Mojave and Great Basin Deserts. Wildlife habitat on SMTS has been modified to a considerable degree by brush fires. Because there is no sport hunting and only a limited amount of pest control, faunal populations are regulated only by the natural controls imposed by the environment and normal predator/prey relationships. Rodents account for almost half of the known species and are, in terms of distribution and relative abundance, the most important group of mammals.

Several species of birds are recorded as either seasonal or permanent residents in the vicinity of SMTS. Resident species include Le Conte's thrasher and black throated sparrow. Other sparrows and finches migrate through the southern Great Basin and utilize the area as a winter feeding ground. Several species remain as winter residents due to an abundance of tumbleweed seed in disturbed areas.

Reptiles observed in the region include eight species of lizards, the desert tortoise, and four species of snakes. The side-blotched lizard and western whiptail are the most frequently observed species. Coachwhips, speckled rattlesnakes, gopher snakes, and western shovel-nosed snakes have been observed infrequently (DOE, 1986).

Table 3.7-1. Common Species at NTS

Common Name	Scientific Name
Vegetation	
Blackbrush	<i>Coleogyne ramosissima</i>
Joshua tree	<i>Yucca brevifolia</i>
Mohave yucca	<i>Yucca schidigera</i>
Red brome grass	<i>Bromus rubens</i>
Wildlife	
Le Conte's thrasher	<i>Toxostoma lecontei</i>
Blackthroated sparrow	<i>Amphispiza bilineata</i>
Side-blotched lizard	<i>Uta stansburiana</i>
Western whiptail	<i>Cnemidophorus tigris</i>
Coachwhip	<i>Masticophis flagellum</i>
Speckled rattlesnake	<i>Crotalus mitcheli</i>
Gopher snake	<i>Pituophis melanoleucus</i>
Western shovel-nosed snake	<i>Chinactis occipitalis</i>
Desert cottontail rabbit	<i>Sylvilagus audubonii</i>
Mule deer	<i>Odocoileus hemionus</i>
Kit fox	<i>Vulpes velox macrotis</i>
Coyote	<i>Canis latrans</i>

Transient animals include desert cottontail rabbits, mule deer, kit fox, and coyotes. Other larger mammals, such as bobcats and mountain lions, are observed occasionally throughout this region of NTS.

3.7.1.3 Threatened and Endangered Species. No federally listed or threatened, endangered species are known to be present at SMTS. The desert tortoise, listed by the federal government as threatened, is found south of SMTS (U.S. Fish and Wildlife Service, 1992).

3.7.1.4 Sensitive Habitats. No wetlands are present at SMTS, and no other sensitive habitats are present on the site. Yucca Flats (Dry) Lake, an ephemeral lake and potential wetland, is located 8 miles east of SMTS.

3.7.2 CTF

3.7.2.1 Vegetation. The CTF is located within an area of previous disturbance and development that is vegetated by rabbitbrush and other invader species (Table 3.7-2). Other plant species found in the vicinity of CTF include saltbush and Indian ricegrass (DOE, 1991a). Crested

Table 3.7-2. Common Species at INEL

Common Name	Scientific Name
Vegetation	
Saltbush	<i>Atriplex confertifolia</i>
Rabbitbrush	<i>Chrysothamnus viscidiflorus</i>
Indian ricegrass	<i>Oryzopsis hymenoides</i>
Crested wheatgrass	<i>Agropyron cristatum</i>
Wildlife	
Sage sparrow	<i>Amphispiza belli</i>
Horned lark	<i>Eremophila alpestris</i>
Brewer's sparrow	<i>Epizella passerina</i>
Black-billed magpie	<i>Pica pica</i>
American robin	<i>Turdus migratorius</i>
Sage thrasher	<i>Oreoscoptes montanus</i>
Sage grouse	<i>Centrocercus urophasianus</i>
American kestrel	<i>Falco sparverius</i>
Long-eared owl	<i>Asio otus</i>
American rough-legged hawk	<i>Buteo lagopus</i>
Prairie falcon	<i>Falco mexicanus</i>
Golden eagle	<i>Aquila chrysaetos</i>
Short-horned lizard	<i>Phrynosoma douglassi</i>
Sagebrush lizard	<i>Sceloporus graciosus</i>
Gopher snake	<i>Pituophis melanoleucus</i>
Western rattlesnake	<i>Crotalus viridis</i>

wheatgrass has been planted along the roadways. No other species were noted on the site.

3.7.2.2 Wildlife. The CTF site supports limited wildlife habitat because the area has been disturbed by previous construction and operation activities. Thirty-seven species of mammals are known to occur in the vicinity of the CTF site. Of these, 18 are rodents, 4 are hares and rabbits, 6 are carnivores (coyotes, long-tailed weasel, and badger are most common), and 9 belong to other groups. Resident populations of mule deer and pronghorn may be found nearby. Pronghorn are found throughout the INEL and are generally considered abundant. Most pronghorn in southeastern Idaho are migratory. During winter, 4,500-6,000 pronghorn, or about 30 percent of Idaho's total population, may be on the INEL (DOE, 1988a). Occasional small herds of elk are also found throughout INEL.

A total of 184 bird species have been observed at various times of the year on the INEL (DOE, 1991a). The sage sparrow, horned lark, Brewer's sparrow, black-billed magpie, robin, and sage thrasher are the most common passerine breeding species. The sage grouse is the most common upland game bird and breeds throughout the site. The most common raptor species found on the INEL during the breeding season include the American kestrel and the long-eared owl. The most abundant raptors observed during the nonbreeding season include the American rough-legged hawk, American kestrel, prairie falcon, and golden eagle.

Nine species of reptiles have been recorded on the INEL. Of these, the short-horned lizard, sagebrush lizard, gopher snake, and western rattlesnake are observed most frequently.

3.7.2.3 Threatened and Endangered Species. No federally listed threatened or endangered plants are found at CTF. The bald eagle is the only animal observed that is listed by the federal government as endangered (U.S. Fish and Wildlife Service, 1992). The bald eagle usually winters on or near the northern portion of INEL and a roosting site for several eagles is located at the Little Lost River, approximately 12 miles southwest. The Swainson's hawk and ferruginous hawk are two additional raptors occurring at INEL which are candidate species for listing as endangered or threatened. Both Swainson's hawks and ferruginous hawks are uncommon migrants, uncommon summer breeders, and rare winter visitors to the vicinity.

3.7.2.4 Sensitive Habitats. No sensitive habitats are present at CTF due to the developed nature of the facility and previous disturbance of vegetation. Temporarily inundated areas appear periodically on the INEL during periods of high water flow in the Big Lost River and provide habitat for migratory waterfowl, shore birds and other wildlife species. Riparian wetland vegetation (primarily cottonwoods and willows) occurs along the Big Lost River and along Birch Creek, approximately 1 mile from CTF.

3.8 CULTURAL RESOURCES

Cultural resources consist of prehistoric and historic districts, sites, structures, artifacts, and any other physical evidence of human activity considered important to a culture or community for scientific, traditional, religious, or other reasons. Cultural resources can be divided into three major categories: archaeological resources (prehistoric or historic), historic resources and structures, and Native American (traditional) resources. For the purposes of this EIS, cultural resources are also defined to include a fourth category, paleontological resources.

Numerous laws and regulations require federal agencies to consider the effects of a proposed project on cultural resources. These laws and regulations stipulate a process for compliance, define the responsibilities of

the federal agency proposing the action, and prescribe the relationship among other involved agencies (e.g., the State Office of Historic Preservation and the Advisory Council on Historic Preservation). Compliance with the requirements of these laws and regulations involves four basic steps:

- (1) Identification of significant cultural resources that could be affected by a Proposed Action or its alternatives;
- (2) Assessment of the impacts or effects of these actions;
- (3) Evaluation of significance of potential historic properties within the area of potential effect (APE); and
- (4) Development and implementation of measures to eliminate or reduce adverse impacts.

In addition to the National Environmental Policy Act, the primary laws that govern the treatment of cultural resources during environmental analysis are the National Historic Preservation Act (especially Sections 106 and 110) and the Archaeological Resources Protection Act; Public Law 74-292 (the National Natural Landmarks Program) (implemented by 36 CFR Part 62) also governs paleontological resources.

Only those cultural resources determined to be potentially significant under the given legislation are subject to protection from adverse impacts resulting from a Proposed Action. To be considered significant, cultural resources (exclusive of paleontological resources which have other criteria) must meet one or more of the criteria established for inclusion on the National Register of Historic Places (National Register). According to these criteria (as defined in 36 CFR Part 60.4), the quality of significance is present in districts, sites, buildings, structures, and objects that demonstrate the following:

- Are associated with events that have made a significant contribution to the broad patterns of history
- Are associated with the lives of persons significant in the past
- Embody the distinctive characteristics of a type, period, or method of construction; represent the work of a master; possess high artistic value; or represent a significant and distinguishable entity whose components may lack individual distinction
- Have yielded, or may be likely to yield, information important in prehistory or history.

Resources must also possess integrity of location, design, setting, materials, feeling, and association. Significant cultural resources, either prehistoric or historic, are referred to as "historic properties."

While paleontological resources do not have the degree of legal protection afforded cultural resources, they are considered and protected under several laws, including the Antiquities Act. Idaho State Code 67:4112-4119 protects "archaeological and vertebrate paleontological sites and resources on public lands in the state" and NTS Standard Operating Procedure 5407 "assures the protection and preservation of any antiquities, historic sites, or threatened and endangered plant species on the NTS" (DOE, 1990). The criteria by which paleontological resources are considered for National Natural Landmark designation are defined in 36 CFR Part 62.5(b).

Once it has been determined that a federal agency's Proposed Action will constitute an undertaking (any project, activity, or program that can result in changes in the character or use of historic properties), the APE must be defined and the historic properties within it identified. The APE for analysis of cultural resources in this analysis (referred to as the region of influence), is different for each location described below.

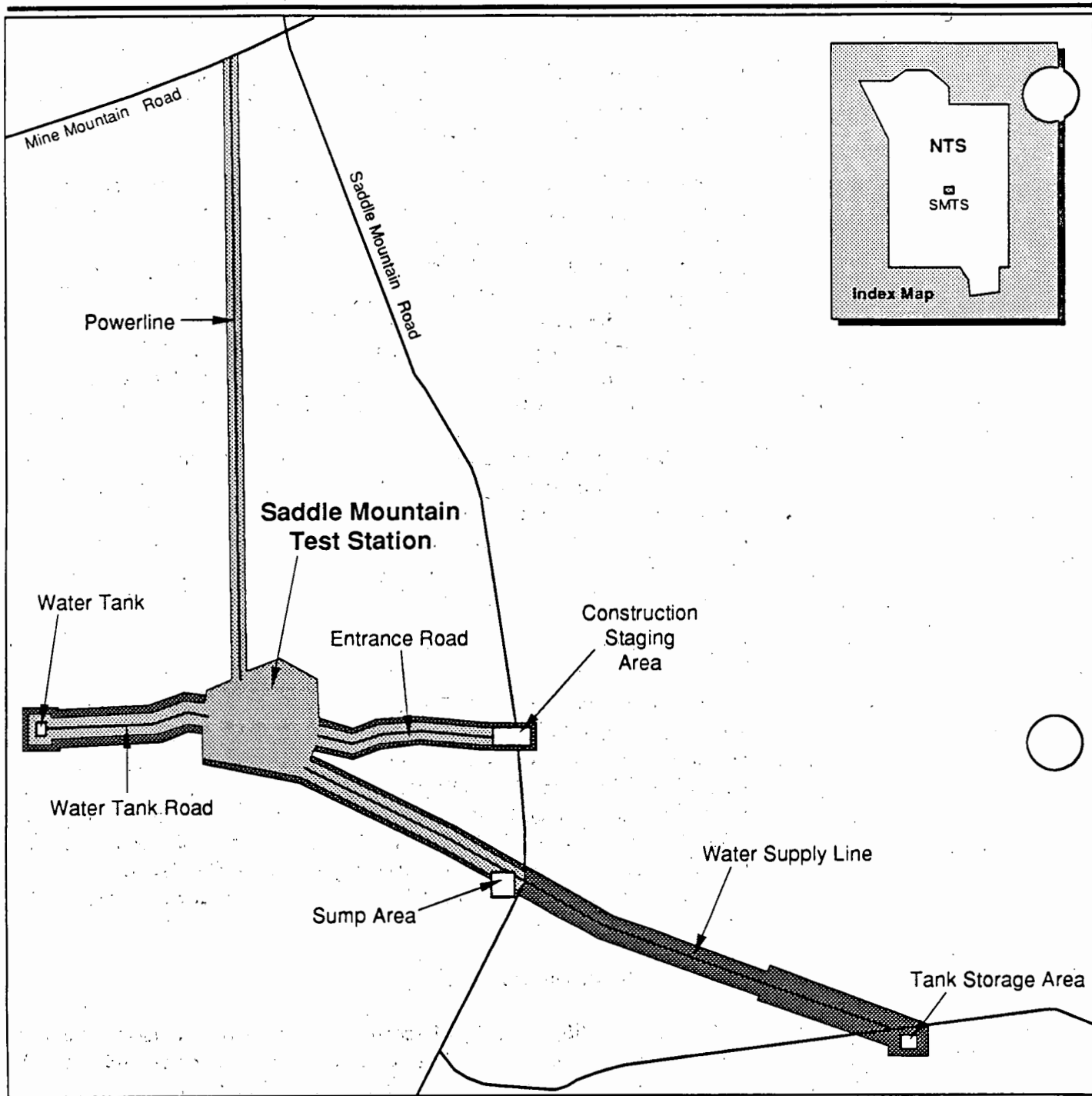
3.8.1 SMTS

The region of influence for SMTS at NTS is the area south of Mine Mountain Road and west of Saddle Mountain Road in a remote, isolated, and undisturbed area known as Mid Valley (see Figure 2.3-2). Mid Valley is bordered by Shoshone Mountain to the west and northwest, Mine Mountain to the east, and Lookout Peak to the south. Human occupation of the area dates from as early as 12,000 years before the present (BP), as evidenced by lithic scatters, diagnostic projectile points, pottery sherds, and other artifacts that have been identified from numerous recorded and unrecorded sites and rock shelters.

Archaeological Resources

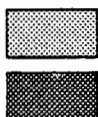
In September 1988, the Desert Research Institute (DRI) intensively surveyed a portion of the region of influence for SNTP program activities (Figure 3.8-1). Three roads, the facility area, and the transmission route were inspected by walking 30-meter (100-foot) transects and five sites were recorded. All sites were small and were collected in accordance with Bureau of Land Management policy; none of the sites were considered eligible to the National Register. The five sites are identified as follows:

- Site 26Ny5776 Pink, non-welded tuff unifacial chopper
- Site 26Ny5777 Obsidian core reduction flake
- Site 26Ny5778 Brown chert Rosegate point and an obsidian core reduction flake



EXPLANATION

Cultural Resources Surveys



1988

1992

Nevada Test Site

SMTS Site Cultural Resources Surveys

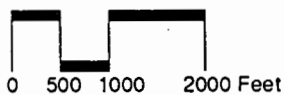


Figure 3.8-1

Site 26Ny5779 Obsidian biface thinning flake

Site 26Ny5780 Six obsidian core reduction flakes, one with a utilized edge.

In May 1992, the remaining portions of the proposed SNTP program area (including the water supply line) were surveyed by DRI using the same survey techniques used in the previous surveys. Two sites were recorded, both of which were isolated surface finds and neither of which is considered eligible to the National Register. The two sites were left undisturbed and are described as follows:

Site 26NY8002 An isolated obsidian biface

Site 26NY8003 An isolated obsidian core reduction flake.

Historic Resources and Structures

Although historic resources are known to exist in the Mid Valley area, no such resources have been identified within the region of influence for SNTP program activities. The closest identified historic site is a campsite (26NY3913) located approximately one mile southwest of SMTS.

Native American Resources

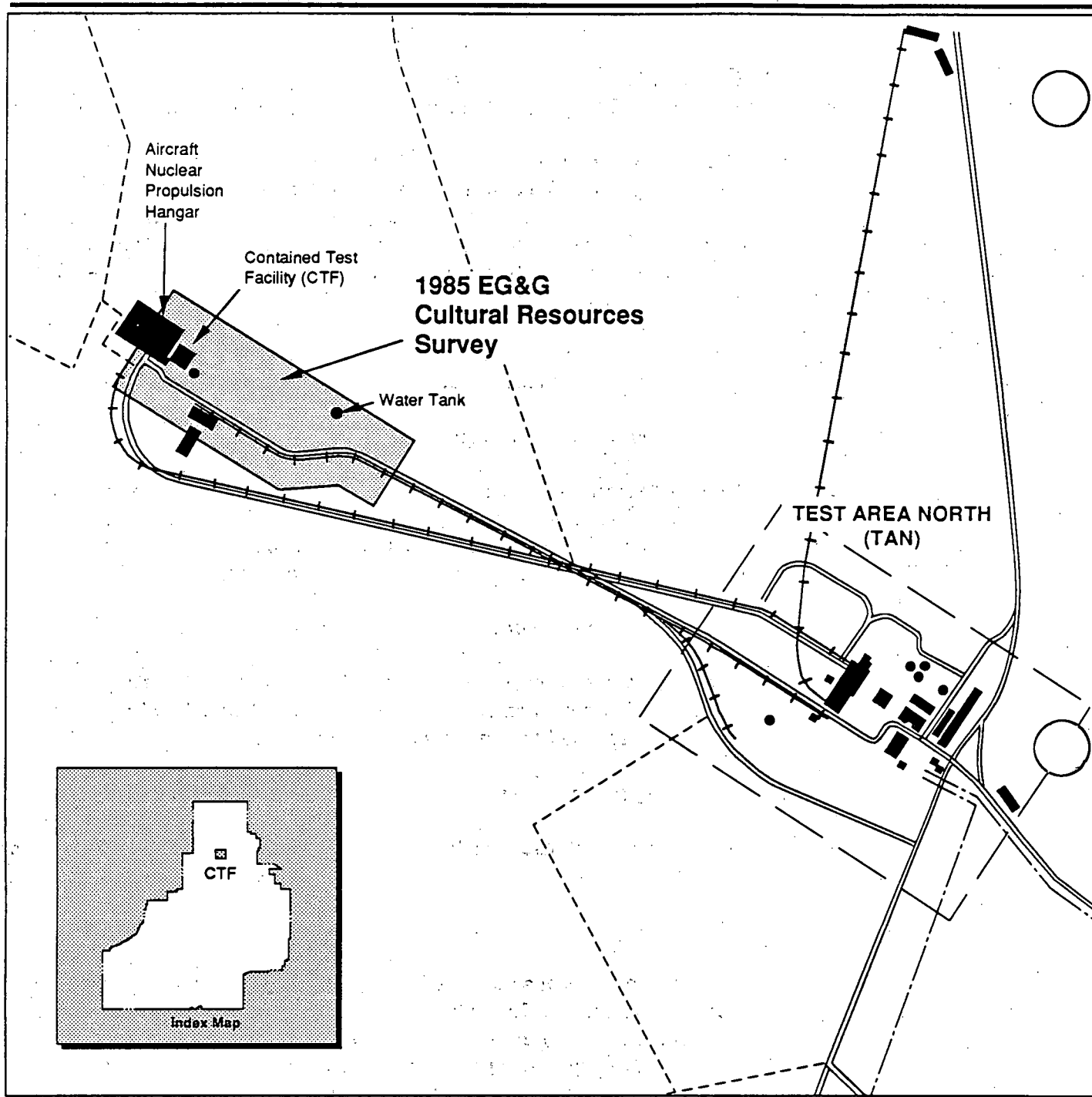
Cultural resource surveys have not identified any Native American resources. Further comments from Tribal groups with cultural ties to the NTS will be solicited through review of the Draft EIS.

Paleontological Resources

No paleontological resources have been identified within the SMTS region of influence.

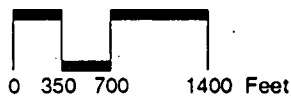
3.8.2 CTF

The region of influence for the CTF is the immediate area around the proposed project site (Figure 3.8-2). Existing facilities, paved roads, and infrastructure already exist and the entire facility area has been disturbed previously through grading and construction, including raising the surface of the site with fill pads by about 15 feet. Archaeological, paleontological, and historical record searches at EG&G Idaho, Inc.'s Cultural Resources Management office in April 1992 verified known cultural resources present at the CTF site, and an inspection of the facilities and grounds was made at that time to locate the archaeological sites and appraise the integrity of standing structures.



EXPLANATION

- Dirt Roads
- Transmission Lines
- 1985 EG&G Survey



Idaho National
Engineering
Laboratory

CTF Site
Cultural Resources
Survey

Figure 3.8-2

Archaeological Resources

Several areas associated with the TAN facility, including CTF, were examined between 1982 and 1985 as a part of a program designed to identify cultural resources in danger of being disturbed through increased installation activities on the INEL (Idaho State University, 1986). In July 1985, an archaeological/paleontological survey of a 100-meter-wide zone (328 feet) surrounding the CTF was conducted by EG&G (Figure 3.8-2); one sparse lithic scatter (10-BT-1234) and one isolated activity area (10-BT-1235) were recorded during this survey. Neither was considered of sufficient significance to be potentially eligible for the National Register (Idaho State University, 1986).

Historic Resources and Structures

The INEL has a long tradition of pioneering advances in science and contains the largest concentration of nuclear reactors in the world; over the years 52 reactors, most of them first-of-a-kind facilities have been built at the INEL (INEL, 1986a). Experimental Breeder Reactor-I, the first reactor built at the INEL and the first to produce commercial electricity by nuclear fission, is a National Historic Landmark.

The CTF is a scaled version (1/5 normal size) of a commercial pressurized water reactor, originally conceived in 1962 as a single-accident test facility. During construction, however, the CTF project underwent several design changes, and construction was not completed until 1975. The first nuclear loss-of-coolant accident simulation was conducted in the CTF in 1978. This experiment simulated the worst possible type event that could happen in a nuclear reactor and was the first time a pressurized water nuclear reactor system had been subjected to such a major event. Although similar full-scale facilities exist (e.g., in Japan), the CTF facility is the only nuclear reactor test facility of its size in the world designed to simulate, as closely as possible, all the important events that could occur during loss-of-coolant accidents and other accidents in commercial pressurized water reactor power plants (DOE, n.d.). Over forty nuclear reactor safety tests were performed at this facility before it was deactivated in 1986; it is currently undergoing asbestos abatement.

Native American Resources

The Northern Shoshone and Bannock tribes of Idaho consider the area of the INEL a part of their homeland. A request has been initiated through the Idaho State Office of Historic Preservation to identify any Native American sacred or ceremonial sites or any group or individual who might have interest in SNTP Program activities; however, no such sites or individuals have been identified.

Paleontological Resources

While fossil camel remains have been identified in the vicinity of the TAN facility, no paleontological resources have been recorded or identified in the CTF site area. Other paleontological resources have been found throughout the INEL (Figure 3.8-3).

3.9 GEOLOGY AND SOILS

Geology and soils includes those physical aspects of the alternative sites related to physiography (landforms), geologic units and structures, seismic and volcanic activity, and surficial soils. The region of influence for soils is the immediate vicinity of the site alternatives; the region of influence for the other aspects is the regional setting as well as the immediate alternative sites.

3.9.1 SMTS

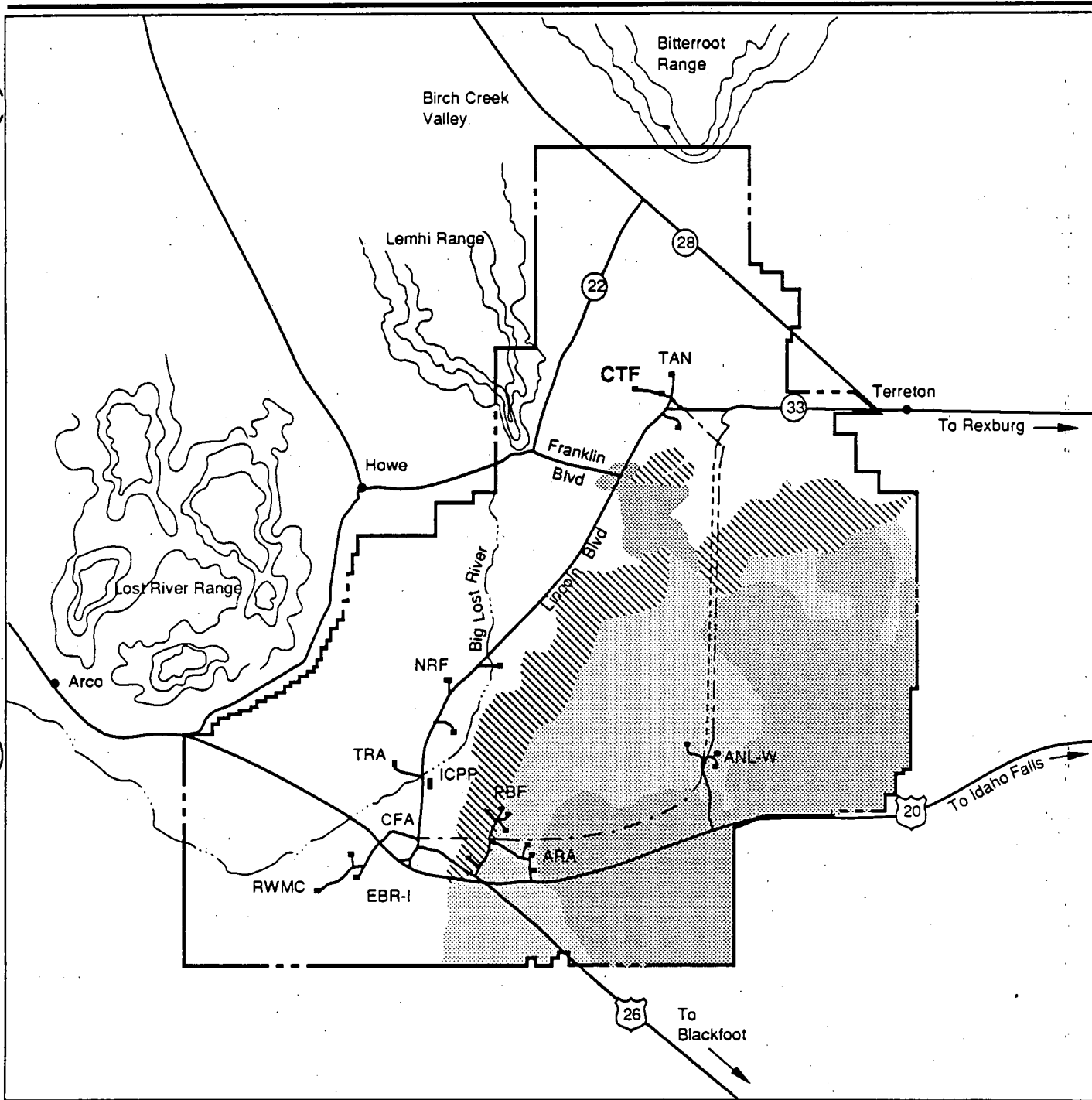
Physiography and Geology

Most of Nevada, including the NTS, is in the Great Basin region of the Basin and Range Physiographic Province. The Great Basin is characterized as a series of north-northeast trending mountain ranges, separated by broad, flat-floored basins. Elevations at the NTS range from 3,000 to 4,000 feet MSL in the basins to over 7,000 feet MSL in the mountains.

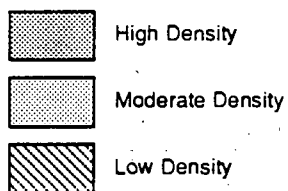
The SMTS is located on the eastern footslope of Shoshone Mountain, in Mid Valley (Figure 3.9-1). The elevation of the SMTS is approximately 4,800 feet MSL.

The mountain ranges in the Great Basin are composed primarily of thick sequences of Paleozoic (approximately 570 to 225 million years ago) sedimentary rocks overlain by Tertiary (approximately 65 to 3 million years ago) rocks made from volcanic ash (tuffs and tuffaceous rocks) and volcanic flows (rhyolite). These mountains were uplifted by roughly parallel block faults, with intervening basins being filled with Quaternary (approximately 3 million years ago to present) unconsolidated sediments (alluvium) that were eroded from the mountains (Stewart, 1980).

Shoshone Mountain is typical of a small block fault mountain in the Great Basin. Surficial rocks in Shoshone Mountain are primarily Tertiary volcanic tuffs and rhyolites, with smaller amounts of Paleozoic dolomites and limestones (Stewart and Carlson, 1978). The SMTS is located on an older, dissected, inactive alluvial fan (Christenson and Purcell, 1985) in the western part of Mid Valley. The SMTS is located on a ridge of alluvium (interchannel) between two active channels that have cut down into the alluvial fan. Slopes at the site range from 5 percent in the interchannel area



EXPLANATION



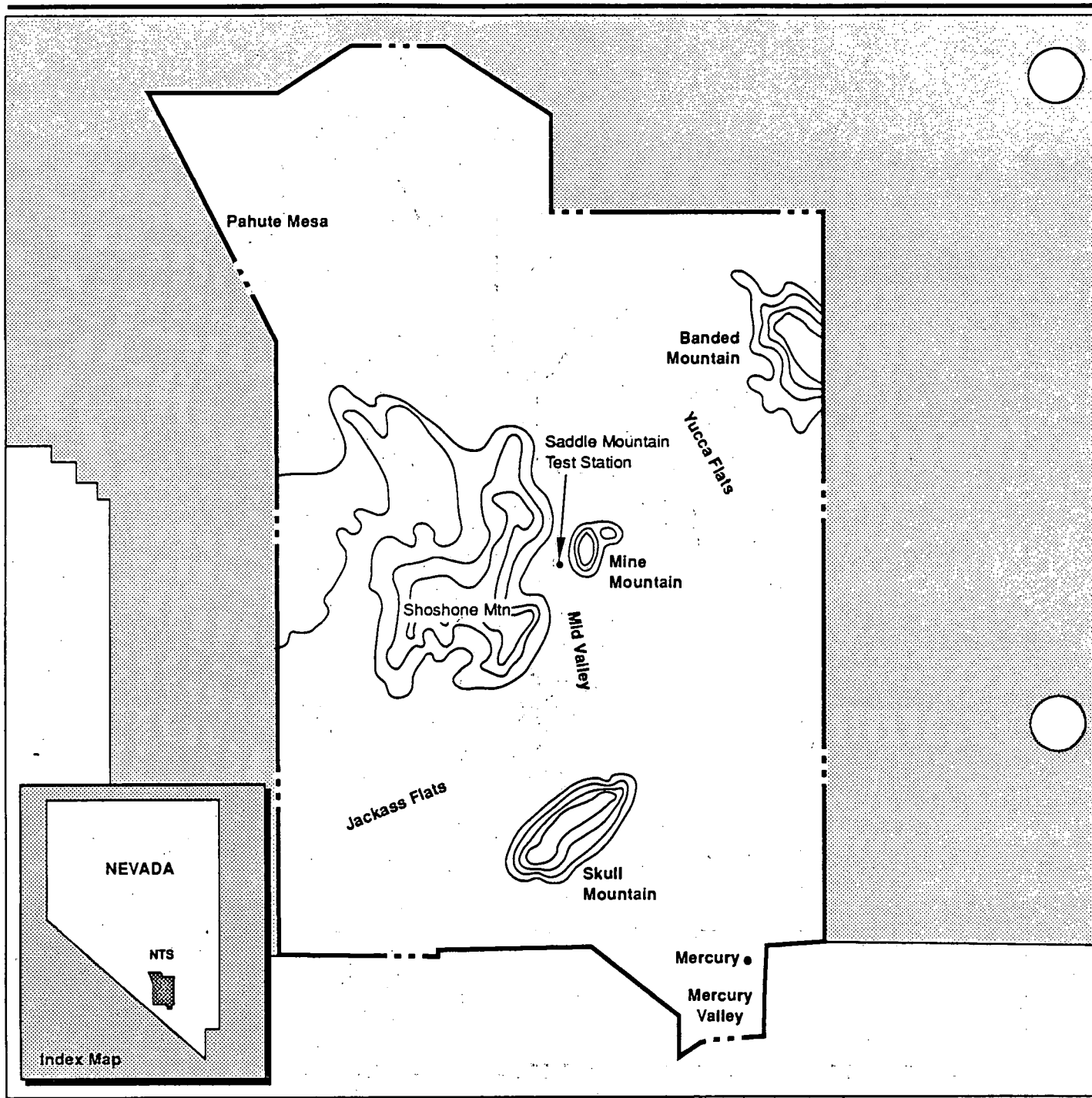
ANL-W - Argonne National Laboratory West
 ARA - Auxiliary Reactor Area
 CFA - Central Facility Area
 CTF - Contained Test Facility
 EBR-I - Experimental Breeder Reactor-I
 ICPP - Idaho Chemical Processing Plant
 NRF - Naval Reactors Facility
 PBF - Power Burst Facility
 RWMC - Radioactive Waste Management Complex
 TAN - Test Area North
 TRA - Test Reactor Area

Idaho National Engineering Laboratory

Paleontological Sensitivity

Figure 3.8-3





EXPLANATION

- Nevada Test Site
-  Nellis Air Force Range

Nevada Test Site

Physiographic and Topographic Features



Figure 3.9-1

to 25 percent along the stream channels that incise the alluvium to depths of 60 to 80 feet.

No mineral ores or construction materials (i.e., aggregate) have been identified at the SMTS.

Typical of the geologic structure of much of the Great Basin, bedrock is cut by several steeply dipping normal faults along the western boundary of Mid Valley. These faults are concealed beneath alluvial deposits at the proposed test facility; their locations are approximated by extension from observed faults to the north and the south (Figure 3.9-2). Because the overlying sediments in the SMTS area do not show displacement from the inferred faults shown on Figure 3.9-2, these faults are considered to be inactive. However, 32 other faults in the general area do show Quaternary movement; dates of the latest movement on these faults have ranged from 40,000 to 2 million years ago (DOE, 1986).

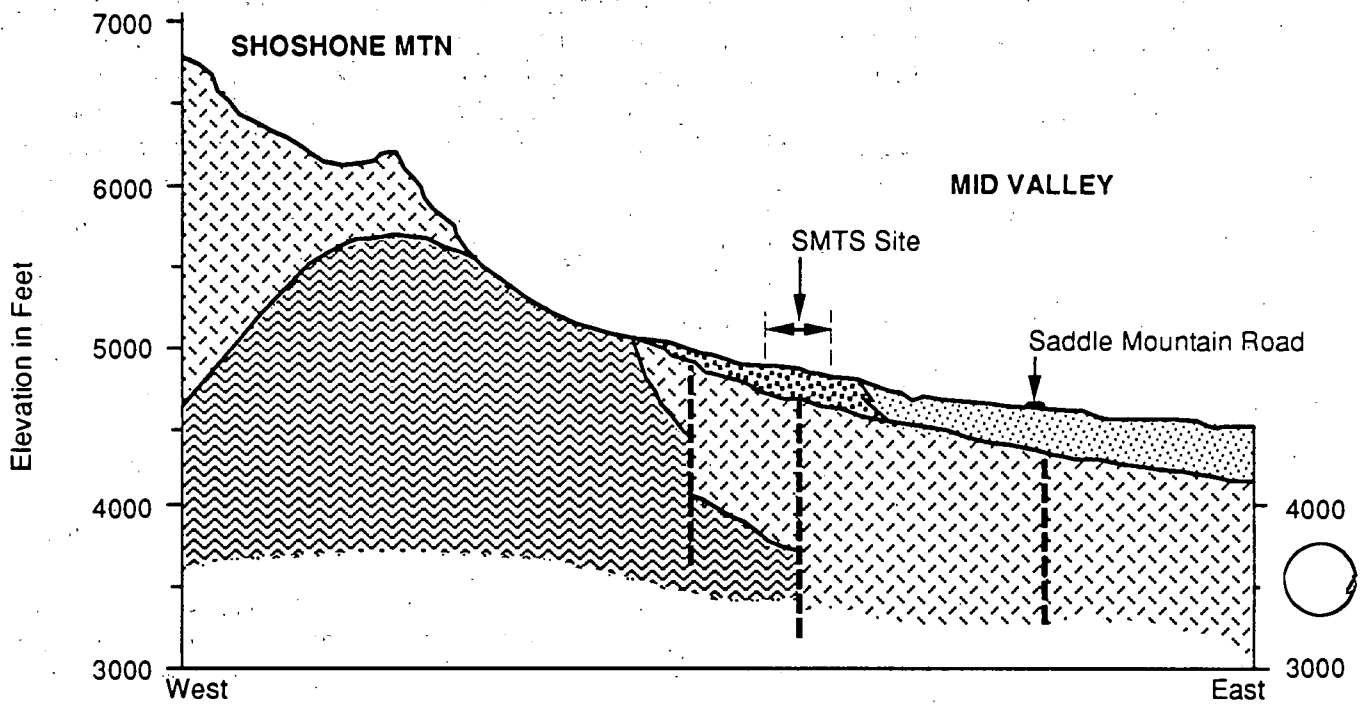
Seismic and Volcanic Activity

Over geologic time, earthquakes in the southern Great Basin have occurred in relatively brief episodes of intense activity in areas that may have been inactive for thousands of years. In any case, current knowledge of Quaternary faulting is not considered sufficient to permit reliable correlations of earthquakes with tectonic processes such as faulting (DOE, 1986).

Underground nuclear explosions at the NTS have caused minor displacements along preexisting faults in the NTS. The prominent Yucca fault in Yucca Flat has ground shock-induced displacement of up to 1.5 feet by nuclear explosions along most of its length of 15 miles. Preexisting faults on Pahute Mesa characteristically exhibit displacement from nuclear explosions, resulting in vertical offsets of about 1 foot or less for distances along the fault of as much as 3 miles.

One aspect of underground testing of nuclear explosives is the generation of ground motion and shock waves that at distances, resemble natural earthquakes. The characteristics of such ground motion depend on the test size, depth of the explosion, and the geologic environment of the test location. Experience has shown that yields above 100 kilotons may cause minor architectural damage in nearby communities outside the NTS boundary.

SNL has initiated a seismic monitoring program to monitor the seismic response of the SMTS to underground nuclear tests as well as to natural seismic events. Data from two recent large underground tests show maximum ground accelerations of 0.003 gravities and 0.1 gravities in the vicinity of the site (SNL, 1991c, 1991d).



Vertical Exag: 2.5 X

EXPLANATION



Younger Alluvium (Quaternary)



Older Alluvium (Quaternary)



Tuff and Tuffaceous rocks (Tertiary)



Dolomite and Limestones (Devonian)



Inactive Faults

Saddle Mountain Test Station

Schematic Geologic Cross Section

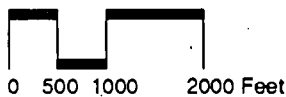


Figure 3.9-2

Mid Valley lies in an area of relatively low historical seismicity and is assigned to seismic risk zone 2 (moderate damage) of the Uniform Building Code (UBC). However, due to the activity induced by the underground testing, all structures at the NTS conform to the requirements of UBC Zone 4 (greatest seismic risk zone). Available data suggest that earthquakes with magnitudes of less than 4.5 on the Richter scale occur with a frequency of less than one per year within 24 miles of the proposed site. The nearest recorded larger earthquake occurred on June 29, 1992, had a magnitude of 5.6, and was centered six miles beneath Little Skull Mountain, approximately 16 miles southwest of the proposed site. Peak ground accelerations from tectonic earthquakes in southern Nevada have not exceeded 0.5 gravities. No information is available on the latest date of movement on the concealed faults that underlie the SMTS and no evidence of any ground-shock-induced displacements has been reported in the Mid Valley area.

Past volcanic activity is evident in the southern Great Basin and suggests the possibility of future volcanism in the region. The most recent explosive volcanic activity in the area occurred more than 7 million years ago at Black Mountain located 28 miles northwest of SMTS. The most recent lava flows in the area occurred an estimated 140 thousand years ago at the Lathrop Wells volcanic center 21 miles southwest of the SMTS (Turrin, 1991).

Soils. The U.S. Soil Conservation Service has not mapped the NTS for detailed soil units and properties; however, other agencies have studied portions of the NTS (Leavitt, 1970; Leavitt and Mason, 1971). Based on nearby data and known geology of the sites, some estimates of soil characteristics can be made.

The proposed SMTS site is underlain by older alluvial fan deposits of Quaternary age (see Figure 3.9-2); these deposits consist of unconsolidated and weakly consolidated mixtures of cobbles and pebbles of welded tuff and limestone in a matrix of silt and sand. Occasional large boulders are found at or near the surface. The percolation rate at the site averages 37 minutes per inch. At various depths the materials are cemented by calcium carbonate into hard concrete-like layers (caliche). These older alluvial materials are estimated to be less than 200 feet in thickness over bedrock at the proposed site.

Alluvial soils are typically loams, or loams with high content of sand, gravel, and/or cobbles. Older fans commonly have stabilized surfaces that minimize erosion. Erosion potential (typically by wind or occasional floods) can be slight or moderate; wind erosion of fine-grained particles is the most-likely event during ground disturbing activities. These types of soils are generally satisfactory for construction of facilities.

3.9.2 CTF

Physiography and Geology

The INEL is located on the Eastern Snake River Plain, a physiographic depression extending from the Idaho-Oregon border on the west to the Island Park-Yellowstone Volcanic Plateau on the east. Volcanic rocks of the Eastern Snake River plain include caldera rhyolites overlain by basaltic lava flows and pyroclastic rocks (rocks formed from rock fragments ejected from a volcano during an eruption). These volcanics often occur interbedded with alluvial, lake bed (lacustrine), and wind-blown (eolian) sediments. The basalt deposits and interbedded sediments thicken from northeast to southwest along the axis of the Eastern Snake River Plain. Figure 3.9-3 shows a geologic cross section of the INEL and CTF. Basin and Range structural features occur adjacent to the Snake River Plain.

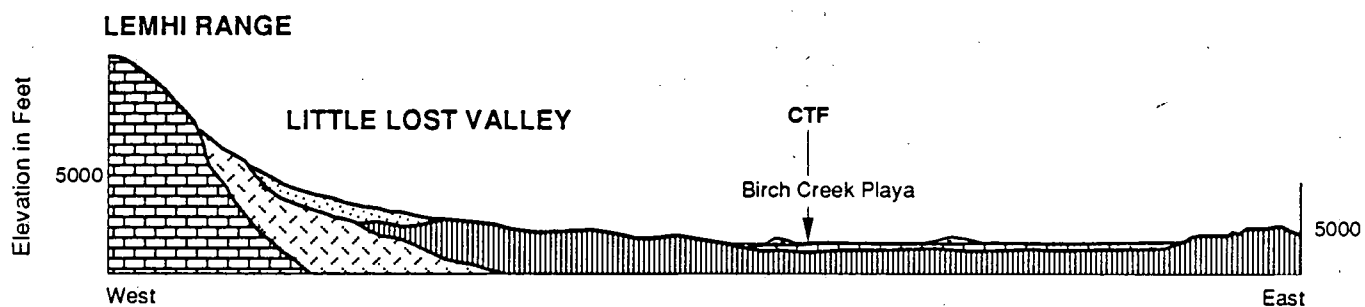
The surface area of the INEL is relatively flat, with predominant relief manifested either as volcanic buttes jutting up out of the desert floor or as unevenly surfaced basalt flows and/or flow vents and fissures. Elevations on the INEL range from 5,200 feet in the northeast to 4,750 feet in the southwest, with the average being 5,000 feet.

The area around the CTF is generally flat, with slight differences in terrain caused by stream incision. The CTF facility is located near the western margin of the Birch Creek playa, a very smooth surfaced ephemeral lake bed that has an elevation of about 4,775 feet at its lowest point. During original construction, the CTF site elevation was raised above the lake bed by fill pads to about 4,790 feet. The playa could be subject to occasional flooding; however, dams upstream minimize the likelihood of flooding.

Seismic and Volcanic Activity

The Intermountain Seismic Belt and the Idaho Seismic Zone are the two major areas of seismic activity near the Eastern Snake River Plain. Although large-magnitude earthquakes do not originate beneath the INEL, large earthquakes do occur in the adjacent seismic belts (DOE, 1984c). The largest reported earthquake, approximately 55 miles west-northwest of CTF had a Richter magnitude of 7.3. Although the shock was felt, no structural or safety-related damage occurred at the INEL.

Five earthquakes have been centered within the Eastern Snake River Plain since 1971, although none has exceeded a Richter scale magnitude of 1. The only earthquake to have its epicenter within the INEL was a 0.7-magnitude event centered 4 to 5 miles east of the NRF. No damage from these earthquakes was reported (DOE, 1984c). The INEL is in Seismic Zone II of the UBC.



Vertical Exag: 10X

EXPLANATION

	Sandy Ridges (Holocene)		Limestones (Carboniferous)
	Basalt Lava Flows (Holocene & Pleistocene)		Sandy and Clayey Silts (Holocene)
	Undifferentiated Volcanic Rocks (Tertiary)		Alluvial Fan Deposits (Holocene)

Schematic Geologic Cross Section through Contained Test Facility (CTF)

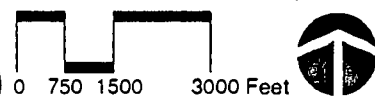


Figure 3.9-3

The likelihood of a sizable earthquake occurring in the vicinity of the INEL in the foreseeable future is extremely slight because of several factors. The Snake River Plain and the Basin and Range Province within about 25 miles of it have very low occurrences of seismic activity; and the Basin and Range structures do not extend into the Eastern Snake River Plain, which shows little evidence of Quaternary faulting except for rift zones associated with basaltic volcanism. Thus it appears that the Eastern Snake River Plain responds very differently to the regional tectonism than does the adjacent Basin and Range Province. A boundary fault has been postulated along the northwestern margin of the Eastern Snake River Plain but no evidence of any movement over the past 6.5 million years has been observed.

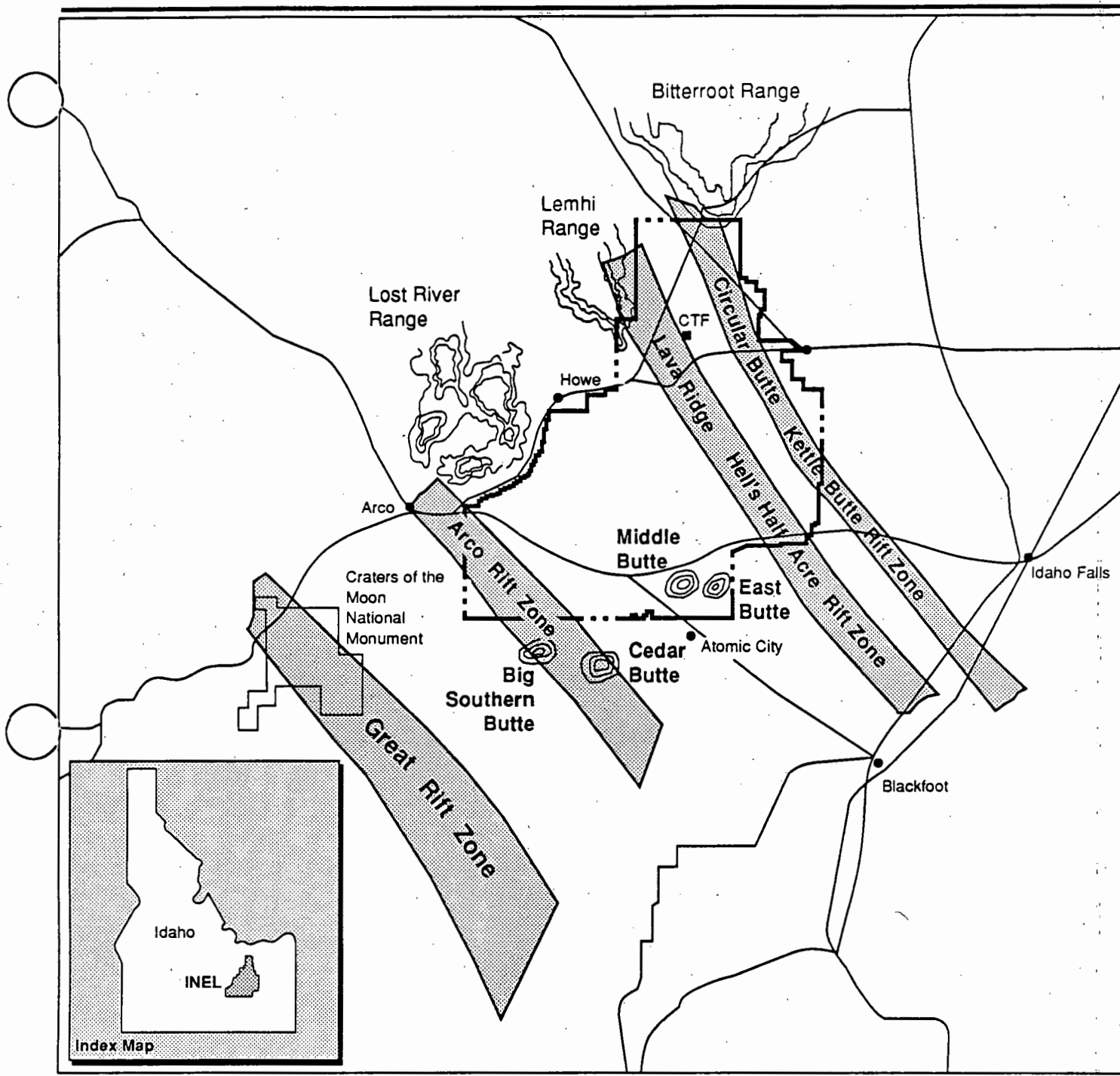
The basalt of the Eastern Snake River Plain upon which the INEL is located, contains several northwest-southeast-trending rift zones that may have formed by extension of the Basin and Range tectonism into the area. These rift zones appear to be the main centers of basaltic eruptive activity. Normal faults, oriented parallel to the boundary of the plain, are exposed in places and show no evidence of recent activity. Geophysical investigations of the subsurface suggest that a fault may be present along the edge of the plain near Arco.

Two major stages of volcanic activity have occurred in the Eastern Snake River Plain over the past 15 million years. Massive deposits of ash-flow tuffs at depth reflect an earlier stage of explosive volcanism from several major eruptive centers within the plain. Over geologic time, the centers of explosive volcanism have migrated progressively to the northeast and are now located in the Yellowstone Plateau nearly 125 miles away. Later stages of non-explosive volcanism, beginning about 4 million years ago and continuing to as recently as 2,000 years ago, produced a thick series of many overlapping basaltic lava flows that issued from many local vents and small craters. The basaltic volcanism is postulated to have originated in several northwest-southeast trending rift zones (Figure 3.9-4).

The CTF site is located between two volcanic rift zones and is underlain by basaltic flows. There are two prominent inactive volcanic craters within 6 miles of CTF.

Soils

The area that includes the CTF is underlain mostly by unconsolidated lacustrine deposits (see Figure 3.9-3). These deposits consist mainly of sandy and clayey silts. Remnants of ancient bars, spits, and beaches that form low ridges consist mainly of sand; the largest such ridge forms a natural north-south trending embankment through the Technical Service Facility. Alluvial deposits flanking Birch Creek in the north consist of gravel, sand, and silt that provide the best source of sand and gravel for construction use in the area. Basaltic bedrock underlies the facility starting



EXPLANATION

----- INEL Boundary

**Idaho National
Engineering
Laboratory**

**Volcanic Structures
and Rift Zones**

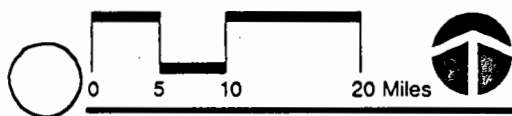


Figure 3.9-4

at depths of about 30 feet. The unconsolidated lake-bed deposits provide suitable natural foundations for light structures, but heavy structures must be supported on bedrock. The finer-grained soils (silts and clays) can be susceptible to wind erosion during and after ground-disturbing activities.

3.10 NOISE

Noise is defined as "unwelcome or unwanted" sound that is usually caused by human activity and added to the natural acoustic setting of a locale. It is further defined as sound that disrupts normal activities or that diminishes the quality of the environment. There are two types of sound sources: stationary and transient. Stationary sources are typically related to specific land uses (e.g., industrial plants); transient sources move through the environment either along established paths or randomly (railroads, roads, flight tracks, etc.). The total acoustical environment of a location is the blend of the background, or ambient acoustics, with the unwanted noise.

Noise is described in terms of sound levels, the measurement of which is usually performed using adjusted decibels (dBA). Typical levels are shown in Figure 3.10-1.

3.10.1 SMTS

The major sources of noise at the NTS are natural physical phenomena from weather and wildlife activities; transient noise is generated by aircraft overflight. The remoteness of the area and the fact that nuclear testing is conducted underground minimizes noise levels at NTS.

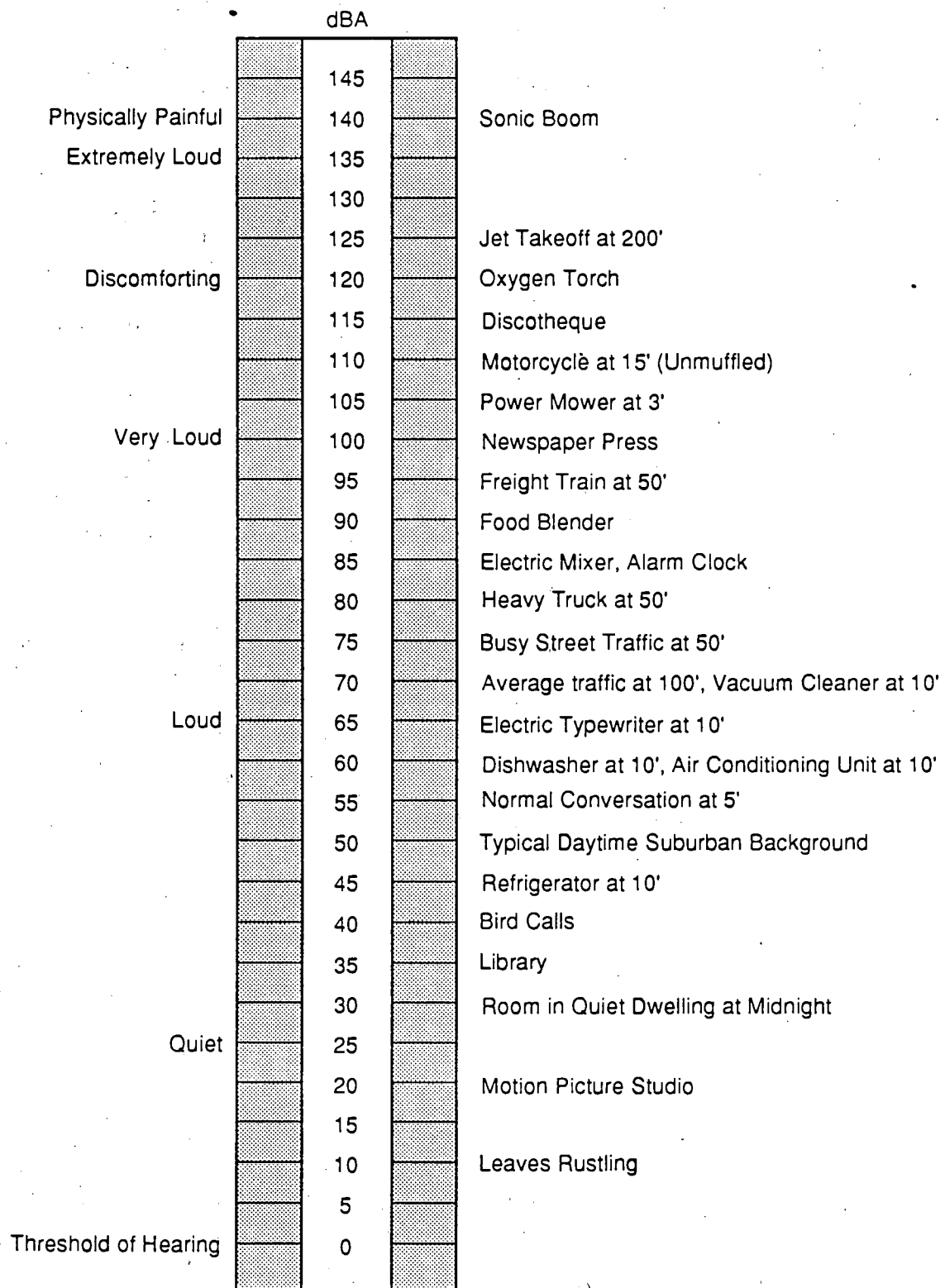
Because the area is remote, noise levels at the SMTS are primarily generated by the natural environment (wind, rain, and the activities of wildlife); noise generated from aircraft overflight is transient. The range for ambient noise levels in this type of remote desert area is between 22 and 38 dBA. The closest sensitive community receptors to the SMTS (e.g., hospitals, schools, and residences) are located approximately 23 miles away at Lathrop Wells; the closest NTS personnel that could be affected by noise levels are located approximately 6 miles away.

3.10.2 CTF

Major noise sources within the INEL include various facilities equipment and machines (e.g., cooling towers, transformers, engines, pumps, steam vents, construction and materials handling equipment, and vehicles).

Since the CTF currently performs no routine facility operations, noise levels are similar to that of the SMTS. Some vehicular traffic noise is produced by the small staff that is performing the decontamination and decommissioning activities, however, that noise, as well as that generated from aircraft

**Figure 3.10-1
Typical Noise Levels of Familiar Sources**



Source: U.S. Air Force, 1987a.

overflight, is transient. Typical ambient noise levels at the CTF site would be below 40 dB. The closest sensitive community receptors to the CTF (e.g., hospitals, schools, and residences) are located approximately 11 miles away in Mud Lake. The closest INEL personnel are personnel in other portions of the TAN (approximately 1.3 miles away).

3.11 WATER RESOURCES

Water resources include surface and groundwater sources of water for the area, including water quality. The region of influence for water resources is, generally, the hydrologic system of the area. More specifically, the region of influence is the source of the water (e.g., stream, river, lake, reservoir, groundwater basin) that would supply water for each alternative site.

3.11.1 SMTS

The hydrology of the NTS has been studied intensively since the mid-1950s, and water quality in and around the site has been monitored since underground nuclear testing began. The U.S. Geological Survey, U.S. EPA, and the DRI have conducted most of these studies.

Groundwater

The groundwater hydrologic systems of the southern Great Basin are characterized by deep water tables and closed groundwater basins that may not correspond to topographic basins. Recharge occurs predominantly by slow percolation from upland areas through the unsaturated zone that overlies the water table. Groundwater in the region occurs chiefly in fracture zones in at least six major aquifers at various levels within limestone, dolomite, and volcanic rock units. The aquifers are commonly isolated from each other by aquitards, relatively impermeable layers that act as a barrier to groundwater movement. In addition, groundwater flow is commonly blocked or diverted by faults and in places where the groundwater reaches the surface as flowing springs. In the deeper aquifers, the water is under artesian pressure. Principal recharge areas for the bedrock aquifers are upland areas and mesas to the north.

Water use in Nevada is governed by the office of the State Engineer and the Division of Water Resources. Chapter 534 of the Nevada Water Laws outlines and delineates the allowable uses of groundwater. Total annual groundwater withdrawals from any given basin may not exceed the perennial yield. Data collected from wells located in Areas 3, 5, and 6 of the NTS indicated that there has been no detectable decline in the static water level and, therefore, no exceedance of perennial yield for the aquifer(s) at these locations (DOE, 1988d) (see Figure 3.2-1). Total withdrawals from wells C and C-1 located in Area 6 of the NTS were 26 million gallons per year (0.07 MGD) (DOE, 1988d).

In the Mid Valley area, groundwater occurs only in deep bedrock aquifers; the alluvial deposits may contain water following rains but do not form perennial aquifers. Groundwater in the proposed water-supply well occurs in tuffaceous aquifers that are probably isolated from the deeper limestone and dolomite aquifers. The static water level in this well is at a depth of 1,663 feet below the surface; the well head is at an elevation of 4,346 feet MSL.

Groundwater in the Mid Valley area is believed to be part of the Ash Meadows subbasin (see Figure 3.2-1). There are 11 NTS wells that currently withdraw water from the Ash Meadows subbasin and 3 that withdraw water from the Alkaline Flat-Furnace Creek Ranch Subbasin.

Surface Water

Surface water in the southern Great Basin occurs principally in interior drainage systems characterized by a dense network of intermittent streams that flow into closed topographic basins known as playas. Typically this water stands on the playas for several days to a few weeks before it is lost, mainly by evaporation. There are 13 playas within a radius of 50 miles of the proposed SMTS site.

There are no perennial sources of surface water in the Mid Valley area. The alluvial fan on which the proposed SMTS site is located is cut by many shallow boulder-dry stream beds that contain water only during and shortly after occasional heavy rains. During rare flash floods streams may be diverted by sediment and cut new channels into easily eroded alluvial deposits. There is, however, no evidence of such flash flooding in the channels bordering the proposed site. Runoff from the precipitation at the proposed site drains into the normally dry Barren Wash which is part of an interior drainage network that terminates in Frenchman Flat, a playa in a closed topographic basin about 16 miles to the east.

Water Quality

Groundwater from the tuffaceous aquifers such as those in the proposed water supply well is generally of excellent chemical quality. It is characterized by relatively high concentrations of sodium and potassium carbonates and low acidity. In general, water in the tuffaceous aquifers meets U.S. EPA primary and most secondary standards for harmful constituents (DOE, 1986) regulated under the Safe Drinking Water Act.

The deep aquifers, slow groundwater movement, and exceedingly slow downward movement of water in the overlying unsaturated zone serve as barriers to transport of radioactivity from underground sources (e.g., underground testing) via groundwater, preventing movement of radioactivity to off-site areas for thousands of years. The estimated average velocity of

groundwater flow through the lower carbonate aquifer in central Yucca Flat is 6 to 600 feet per year (DOE, 1990a).

Groundwater is the only local source of drinking water in the NTS area. Drinking and industrial water-supply wells for the NTS are produced from the lower and upper carbonate aquifers, the volcanic aquifer, and the valley-fill aquifer. Though a few springs emerge from perched groundwater lenses at the NTS, discharge rates are low, and spring water is not currently used for DOE activities. South of the NTS, private and public supply wells draw water from the valley-fill aquifer.

Groundwater sampled from a borehole approximately 20 miles southwest of the SMTS had a pH of 7.7, 216 milligrams per liter (mg/l) of dissolved solids, and relatively high concentrations of silica (45 mg/l), sodium (57 mg/l), and bicarbonate (143 mg/l).

There are no known incidents of groundwater contamination (e.g., fuel spills, solvents) in the vicinity of the SMTS location.

3.11.2 CTF

Groundwater

Large volumes of groundwater occur in the bedrock aquifer beneath the Snake River Plain. The water occurs chiefly in fractures and voids in the basaltic lava flows that underlie the plain. In INEL, the ground water flows to the south and southwest and discharges about 6.5 million acre-feet (1 acre-foot equals approximately 326,000 gallons) annually to springs that feed the Snake River below Twin Falls, 100 miles from INEL. Groundwater flow rates range from 5 to 20 feet per day. Depth to the water table ranges from about 200 feet in the northeast to 1,000 feet in the southern part of the INEL. Recharge to the Snake River Plain aquifer is primarily by infiltration from streams to the northwest, north, and northeast of INEL, especially the Big Lost River.

The DOE Idaho Field Office has negotiated with the Idaho Department of Natural Resources a claimed water right for 81 cubic feet per second, not to exceed 1.5 billion cubic feet (approximately 11 billion gallons) per year withdraw capacity, under the Federal Reserve Doctrine. The state of Idaho has signed a Settlement Agreement and there have been public hearings. Based on these hearings, an Interlocutory Order will be generated. The INEL will abide by this Order as it affects water use until the adjudication process is complete. Currently, INEL withdraws up to 6 MGD, with an average of 37 million gallons per year (DOE, 1991).

Surface Water

The surface water hydrology of the INEL is dominated by the Pioneer Basin, a closed drainage basin that receives water from Big Lost River, Little Lost River, and Birch Creek (Figure 3.11-1). These rivers are supplied by mountain watersheds located to the north and northwest.

The Big Lost River is the major river on the INEL. This river flows intermittently onto the INEL site across the southwest boundary, curves to the northeast, and terminates at the Big Lost River playas (sinks). Last surface flows occurred in 1986. The major storage and diversion structures on the Big Lost River are the Mackay Dam and the INEL flood diversion dam.

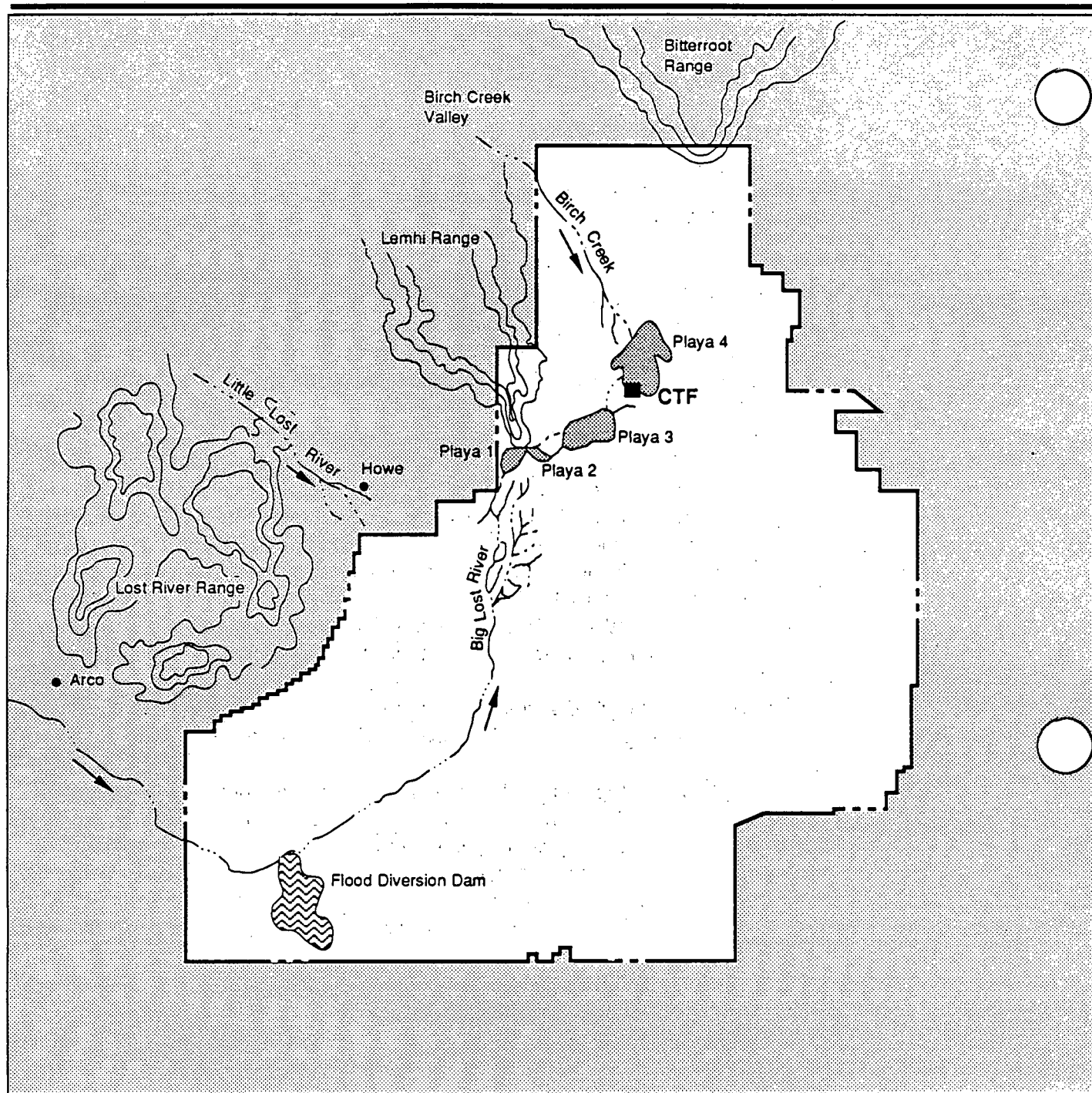
Under normal conditions, most of the flow from the Little Lost River and from Birch Creek is diverted for irrigation before reaching the INEL. In high-flow years, however, Little Lost River and Birch Creek flow onto the site. There, the remaining water evaporates or infiltrates into the ground through the stream channel or playa bottom (DOE, 1984b). Because of the upstream diversions of water, flooding under normal conditions does not occur within the INEL. A maximum possible flood resulting from maximum flows combined with upstream dam failure would inundate the entire Big Lost River floodplain as well as the playas in which the river terminates.

The INEL flood diversion system consists of a small dam that functions to divert the river flow away from INEL facilities into four spreading areas.

The CTF and the entire TAN are located within the margins of the Birch Creek playa. The playa is the terminus of both Birch Creek and Big Lost River, and has a minimum elevation of approximately 4,775 feet MSL. The playa is normally dry and contains discontinuous shallow pools of water only for short periods after heavy rains. Because of the upstream diversions for irrigation, waters from Birch Creek and Big Lost River do not reach the playa under normal conditions. Maximum flow conditions in these streams combined with the failure of water control structures, however, would flood the playa to undetermined depths. Flood control facilities have been constructed in the CTF area to prevent flooding of the CTF. These flood control facilities consist of low dikes and interconnected drainage ditches.

Water Quality

Groundwater quality in the Snake River Plain aquifer in the vicinity of INEL meets drinking water standards (DOE, 1991a). The average total dissolved solid content at INEL is low, ranging from 200-255 mg/l consisting mainly of calcium, magnesium, sodium, and potassium. The composition of the groundwater indicates reaction with minerals in rocks of the surrounding mountains and alluvial valleys where the residence time of the groundwater is relatively long.



EXPLANATION



Playa



Water Diversion Area



Flow Direction



Idaho National
Engineering
Laboratory

Surface Water
Features

Figure 3.11-1

Waters from the Snake River Plain aquifer on the INEL are relatively low in the sum of dissolved constituents (about 200 mg/l). The low mineralization reflects the moderate to abundant precipitation in the mountainous source areas, the absence of extensive deposits containing highly soluble minerals and the low solubility of the basaltic rocks that form the principal aquifer system. The water in the aquifer has a low dissolved solid content and, with little or no treatment, is suitable for most uses. The INEL was placed on the NPL during 1989 to facilitate remediation and monitoring of contaminated areas including an injection well located at TAN in close proximity to the CTF.

3.12 HEALTH AND SAFETY

3.12.1 Existing Safety, Security, and Radiological Monitoring Systems

This section presents background information concerning existing conditions at both NTS and INEL. This includes security and fire protection, operational safety and emergency response procedures, and the existing radiological conditions and monitoring systems. The regions of influence for health and safety are the areas surrounding the alternative test sites which could be affected by test operations or credible accidents, and the area along transportation routes used for shipment of project-related materials. The areas within 150 km of each test site were analyzed for radiological effects.

3.12.1.1 NTS

Public Safety

NTS is a limited access, controlled facility with public access prohibited. It is bordered on three sides by the Nellis Air Force Range. Road access to the NTS is restricted by guard stations and barricades. Mobile patrols are employed to provide security throughout the NTS. All personnel on the NTS are required to wear identification badges containing a thermoluminescent radiation dosimeter which is used to measure the amount of ionizing radiation each individual might receive while on site.

All air traffic over the NTS is restricted and the airspace is monitored by radar; any unauthorized aircraft can be intercepted by Air Force aircraft and escorted to the Desert Rock Airport, three miles south of Mercury, Nevada, for purposes of identifying the pilot and his intentions. The airspace over the Nellis Air Force Range is also restricted. Emergency procedures have been set up so that an inadvertent large release of radioactive gas from an underground nuclear event would not endanger air traffic. Communications systems are in place so that, if needed, air route traffic controllers would be notified of the location of the radioactive cloud and they, in turn, could re-route air traffic as required.

The Nye County Sheriff's office is the primary law enforcement entity on the site and has authority to control ground traffic and make arrests. An office is maintained at Mercury, Nevada, and the sheriff's deputies are authorized to enter most facilities on the site for law enforcement purposes. The State Police and the Federal Bureau of Investigation are not represented on the site; however, they respond to calls for assistance from either the Nye County Sheriff or from the NTS Security Organization.

NTS maintains a contractor security force to ensure necessary protection for government property; transport, handling, and protection of special nuclear material; and response to sabotage, espionage, terrorist activities, or other hostile acts. Security personnel are trained in methods for the safeguarding of special nuclear materials and are equipped with armament, weapons, and specialized transportation to effectively deal with hostile threats. In addition, the NTS security force is deputized by Nye County to assist in law enforcement activities.

Temporary roadblocks are established when needed to control access to designated testing areas in connection with the detonation of underground nuclear devices. The designated forward areas usually include all areas north of Control Point 1 (CP-1) the command and control center for nuclear testing at NTS (see Figure 2.3-2). These areas are "swept" by guard patrols to assure that all personnel have withdrawn to a designated safe location. Helicopters and light aircraft are available to the security force and are normally used to check perimeter barricades and other remote locations in the forward test areas as a part of this sweeping action.

The Department of Energy Nevada field office (DOE/NV) maintains a fully equipped fire department at NTS which is staffed by professional fire fighters and augmented by fire protection engineering personnel. There are three fire stations (Mercury, Area 6, and Area 12) with a complement of nine fire apparatus ranging from structural to aircraft crash rescue. In addition, rescue, mobile command post, and all-terrain vehicles are provided. Additional assistance can be requested from other fire departments as provided for in Memorandums of Understanding with the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service.

DOE/NV maintains an Emergency Operations Center (EOC) in Las Vegas, Nevada, which provides oversight during emergencies at all installations under their jurisdiction, including the NTS. The EOC provides long-term communications and coordination with emergency response resources. It is staffed with trained and experienced personnel and is equipped with facsimile machines, computer networks, radios, cellular phones, and other state-of-the-art communications equipment.

CP-1 coordinates all operational activities at the NTS. In addition to exercising control authority associated with underground testing, it

coordinates activities of both the National Oceanic and Atmospheric Administration (NOAA) and Environmental Protection Agency (EPA) and maintains an elaborate communications and data acquisition network to support event-based testing.

Under DOE auspices, EPA has established an off-site environmental surveillance network, currently including 19 Community Monitoring Stations. Each station has a suite of samplers and recorders, including a pressurized ion chamber (PIC). All of these monitoring stations are equipped to telemeter PIC information via satellite directly to a Control Point on the NTS. Each of these stations is managed by a member of the community in which the station is located, usually a science teacher from the local school system.

The BLM has a large automated network of meteorological stations telemetering data by satellite. These stations are sited on a roughly 75-mile grid covering most of the western U.S. The EPA, in an agreement with BLM, has instrumented 10 of these stations with PICs to collect external gamma exposure rate data. The system also provides a broad spectrum of meteorological data from a significant number of stations for use by the Weather Service Nuclear Support Office (WSNSO) in radioactive cloud transport/dispersion assessments.

The WSNSO provides all meteorological services required on the NTS. It carries on investigations and research into meteorological processes, prediction methods, and fallout phenomenology. It also researches data acquisition, processing, and display techniques for improving meteorological support to assist the DOE in performing its mission. WSNSO is responsible for conducting a broad meteorological program in support of both nuclear and non-nuclear projects.

During a nuclear test, additional resources are deployed in and around the NTS to provide increased radiological monitoring capability. These include:

- A Bluebird Team consisting of monitoring personnel with appropriate radiation detection instruments to provide close-in radiological monitoring of any potential effluent.
- EPA Monitors at standby locations in or near the estimated off-NTS downwind fallout locations, are determined prior to the event. If a radioactive release occurs, these mobile monitoring personnel are positioned to perform off-site radioactive monitoring and sampling.
- Aircraft, including a helicopter and fixed-wing aircraft, with radiological monitoring capability can be deployed for each nuclear event.

A 24 hour per day Radiological Assistance Team with support from numerous DOE, contractor, and user agency personnel is available. NV is also DOE's Federal Radiological Management and Assessment Center (FRMAC) lead field office which coordinates all federal agency response to a significant radiological emergency. NV also manages the Nuclear Emergency Search Team which maintains extensive aerial and ground radiological monitoring capability.

Safety documentation is written, as necessary, to support operations conducted at NTS. The sponsoring laboratory or agency provides an operations plan that covers safeguards and security, and radiological, environmental, and personnel safety. An Operations Permit is issued once radiological, environmental, health, safeguards, and security concerns are satisfied.

Environmental Radiation Monitoring

DOE is responsible for providing radiological safety services on the NTS and maintaining an environmental surveillance program designed to control, minimize, and document exposures to the NTS working population and the off-site public population. The results are reported annually in environmental reports (DOE, 1990a).

Documented standard operating procedures have been established for radiological monitoring conducted at the NTS. The Radiation Safety Manual for the NTS outlines standard operating procedures for radioactive materials control, shipment of radioactive material, radiological safety in specific test areas, and waste management (DOE, 1988c).

Under an Interagency Agreement with DOE, U.S. EPA conducts the off-site radiological monitoring program around the NTS. The routine surveillance program includes pathways monitoring that consists of air, water, and milk surveillance networks surrounding the NTS, and a limited animal and vegetable sampling program. The EPA's extensive off-site environmental surveillance system around the NTS has measured no radiological exposures that can be attributed to current NTS operations.

The Off-Site Radiological Safety Office (EPA/EMSL) is responsible to the Test Controller and the NTS Manager for providing off-site radiological safety services in accordance with NTS-SOP 5402 and the Interagency Agreement (DE-AI08-86-NV10522). Emergency preparedness responsibilities are established as outlined in DOE Orders 5500.2 and 5480.1A, along with NTS-SOP 5501. All essential test-related personnel receive basic radiological safety training and any additional training required for their job assignments.

3.12.1.2 INEL

Public Safety

INEL is a limited access, controlled site that significantly limits the presence of the general public anywhere within the interior portions of the site and from access to the nuclear facilities. Access by visitors to and from individual sites is controlled at all times and only those authorized are allowed on site; everyone entering must have an appropriate security badge. All personnel and visitors entering any nuclear facility receive a thermoluminescent radiation dosimeter while in the area, which is used to determine the dosage of radiation which each individual might receive while on site.

The airspace over the INEL is designated by the FAA as a National Security Area, and access is limited to above 6,400 feet mean sea level (MSL). Communication systems are in place so that air route traffic controllers can advise the local transient aircraft of abnormal conditions in the area.

INEL maintains a contractor security force to ensure necessary protection for government property; transport, handling, and protection of special nuclear material; and response to sabotage, espionage, terrorist activities, or other hostile acts. Security personnel are trained in methods for the safeguarding of special nuclear materials and are equipped with armament, weapons, and specialized transportation to effectively deal with hostile threats. The security forces are also equipped with two helicopters for INEL patrol, including pre-test surveillance and clearing of restricted test areas. In addition, the INEL security force is deputized by the adjacent counties to assist in law enforcement activities. The state and federal roads that cross the INEL are patrolled and enforced by the Idaho State Patrol and the local county sheriffs' offices.

Access to the grazing areas around the INEL is monitored and patrolled by the INEL security force to ensure the grazing boundaries are honored and maintained. The central portion of the INEL is also frequently swept for unauthorized access. The nuclear facilities, including Test Area North (TAN) and the Contained Test Facility (CTF), are patrolled 24 hours a day.

The INEL maintains a well-trained and fully equipped fire department. There are 3 fire stations (TAN, CFA, and Argonne National Laboratory-West sites), equipped with a total of four engines, one tanker, three brush fire fighting units, one rescue unit, and several other vehicles for brush fire response. Additional assistance can be requested from community fire departments, as provided for in Memorandums of Understanding with the BLM and local communities.

The INEL EOC serves as the center for oversight of emergencies at the INEL providing for long-term communications with off-site agencies, and for coordinating INEL resources in response to requests by off-site authorities. The EOC is staffed with trained and experienced personnel and is equipped with facsimile machines, computer networks, radios, cellular phones, and land-line telephones.

The INEL has an around-the-clock quick response field monitoring team to provide timely measurement and reporting of release to the environment of radiological materials. This initial quick response capability is backed up by a second phase response of multiple field monitoring teams. The teams use standardized and state-of-the-art equipment in their response. The INEL field monitoring teams are integrated in their response with the INEL-implemented Region Six Radiological Assistance Programs and other national response teams such as the Nuclear Emergency Search Team and the Accident Response Group. A Mobile Emergency Response Van equipped with communications, radiological monitoring, and gamma spectroscopy equipment is included in the radiological response capabilities at the INEL. Specialized alpha radiation monitoring equipment and personal protective equipment are also available.

Individual SARs are written for each reactor facility at the INEL (see Section 4.12.1). The sponsoring laboratory or agency provides radiological safety plans for each test series which cover all operations. They include radioactive effluent documentation, surveys for radiological safety, cleanup and pollution control procedures, instrumentation types and deployment, and any other radiological safety features pertinent to operations at the INEL.

Environmental Radiation Monitoring

Environmental monitoring programs at the INEL are conducted by DOE to determine (1) the overall impact of operations on the environment, (2) whether environmental levels of radioactivity comply with applicable standards (40 CFR Part 61, DOE Order 5400.5), (3) whether containment and control systems at facilities are functioning as planned, and (4) long-term trends of concentrations of radioactivity in the environment and any changes in those trends. Environmental impacts are determined by measuring radionuclides in the environment, where such measurements are possible, or by modeling the transport of radionuclides through environmental pathways in cases where environmental concentrations are too low to measure. Measurements on the INEL or at the INEL boundary are frequently compared to similar measurements at background or control locations. Where radionuclide concentrations are high enough to be measured regularly, long-term trends are presented. Data are reported yearly in an environmental monitoring report for the INEL (DOE, 1990b).

The environmental pathways by which radioactivity could affect the population in the vicinity of the INEL are through direct radiation exposure, through atmospheric transport, and through soils, water, foodstuffs, and/or animals. The environmental monitoring program for the INEL site and vicinity includes the collection and analysis of samples from these potential exposure pathways.

Air and water are routinely monitored for radioactivity at a number of on-site, as well as boundary and distant, locations. Concentrations of radionuclides in milk, wheat, and lettuce samples are measured at site boundary and distant locations. Distant locations serve as background controls that are not affected by radioactive releases associated with INEL operations. On-site soils are sampled annually on a rotating basis, while off-site soils are sampled only in even-numbered years. Environmental radiation exposure rates are measured at the site boundary and at distant locations. Based on available monitoring data, no significant concentrations of radionuclides from the INEL have been detected.

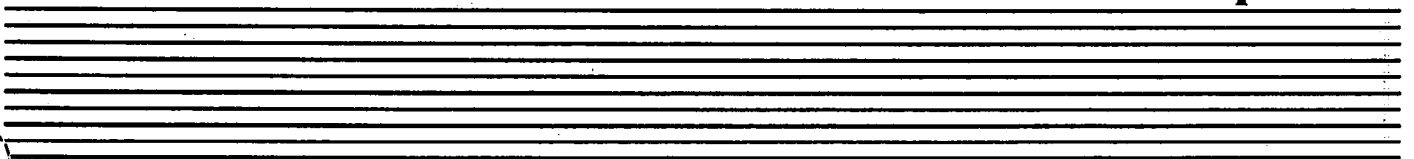
3.12.2 Natural Environmental Radiation

A large contributor to natural radiation in the environment comes from background sources, which include cosmic radiation, naturally occurring terrestrial radioactive materials, and natural internally deposited radioactive materials. These sources account for a large part of radiation exposure received by every individual on an annual basis, and can vary from location to location depending upon such factors as elevation of an area (increased cosmic radiation) and the presence of varying amounts of mineral deposits (increased terrestrial radiation). At NTS these sources contribute a total whole-body dose of 125 millirems per year (mrem/yr), while at INEL they contribute a total whole-body dose of 144 mrem/yr. In addition to the above sources, several other minor sources of radiation which can influence the total individual whole-body dose include medical and dental X-rays (92.5 mrem/yr), global nuclear weapons test fallout (4.6 mrem/yr), various consumer and industrial products (1 mrem/yr), and air travel (1 mrem/1,000 miles) (Glasstone and Sesonske, 1981). Finally, radon gas present in the environment contributes an exposure of 200 mrem/yr to the average person in the United States (NCRP report No. 93). Together the contribution of all these sources produce the natural radiation exposure received by each individual. In the vicinity of NTS, a person typically receives a natural dose of approximately 422 mrem/yr while at INEL a person typically receives a natural dose of 441 mrem/yr. These are shown in Figure 4.12-1.

Both the NTS and INEL host ongoing activities which could result in the release of small quantities of radioactive material. At NTS activities include underground testing of nuclear weapons, and wastes generated by NTS activities. The dosage received by any individual in the vicinity of NTS as a

result of airborne releases from these activities is reported annually based upon computer modeling results (per NESHAP), and is much less than 1 mrem. At INEL activities include operation of nuclear reactors, and wastes generated by INEL activities. The dosage received by any individual in the vicinity of INEL as a result of this activity is also reported annually (per NESHAP), and is also much less than 1 mrem. In both cases the reported maximum individual dose is well below the permissible NESHAP limit of 10 mrem/yr, and impacts associated with each site represent unmeasurable increases above the reported natural doses.

Chapter 4



4.0 ENVIRONMENTAL CONSEQUENCES

4.1 INTRODUCTION

This chapter discusses the potential environmental consequences associated with implementation of the Proposed Action at the two alternative sites, as well as the consequences of the No-Action Alternative. To provide the context in which potential environmental impacts may occur, discussions of potential changes to land use, transportation, and community and public utility services are included in this Environmental Impact Statement (EIS). In addition, issues related to current and future management of hazardous materials and wastes are discussed. Impacts to the physical and natural environment are evaluated for air quality, biological resources, cultural resources, geology and soils, noise, water quality and health and safety. These impacts may occur as a direct or indirect result of program activities. No actions were identified that would contribute to potential cumulative impacts to the environment at either of the two alternative sites.

Means of mitigating adverse environmental impacts that may result from implementation of the Proposed Action at the two alternative sites are discussed. Mitigation measures are suggested for those components likely to experience substantial and adverse changes under these alternatives.

4.1.1 Local Community

This section discusses the potential effects on the two identified regions of influence as a result of implementation of the Proposed Action. The effects of implementing the particle bed reactor (PBR) validation testing include those on population and employment.

4.1.1.1 Saddle Mountain Test Station (SMTS). It is estimated that a maximum of 263 persons would move into the area as a result of this project being implemented. This represents an increase of less than 0.04 percent in the region of influence population. For modeling purposes, this estimation is based on a peak year increase of 100 employees (direct jobs) and assumes for purposes of determining maximum impact that no persons from the local job market would be employed. A dependent factor of 2.63 is included with each direct job, to include families and other dependents associated with these employees (1990 U.S. Census Data). No secondary employment positions were modeled in this analysis.

Direct employment would result in a 2 percent increase in total peak year employment at the Nevada Test Site (NTS), to a total of approximately 5,100.

4.1.1.2 Contained Test Facility (CTF). It is estimated that a maximum of 263 persons would move into the area as a result of this project being implemented. This represents an increase of 0.2 percent in the population of the region of influence. For modeling purposes, this estimation is based on a peak year increase of 100 employees (direct jobs) and assumes for purposes of determining maximum impact that no persons from the local job market would be employed. A dependent factor of 2.63 is included with each direct job, to include families and other dependents associated with these employees (1990 U.S. Census Data). No secondary employment positions were modelled in this analysis.

Direct employment would result in an increase of less than 1 percent in total peak year employment at Idaho National Engineering Laboratory (INEL) to a total of approximately 11,700 jobs.

4.2 INFRASTRUCTURE

4.2.1 SMTS

4.2.1.1 Energy. The added distribution line connecting SMTS to the 1.5 megawatt (MW) NTS electrical distribution line 2.4 miles to the north would provide sufficient electrical power to meet the sub-scale facility (PBR Integral Performance Element Tests [PIPET]) peak power requirements of 0.75 MW over a duration of a few hours. Supplemental power would be provided with mobile generators to support high demand for short periods of time during ground test article (GTA) operational testing.

4.2.1.2 Solid Waste. It is estimated that the amount of non-hazardous solid waste generated from this project would equal an average 175 tons per year over the life of the project. At the NTS, this amounts to less than 2 percent of the total amount of solid waste deposited on an annual basis. The increase in solid waste demand would result in a negligible decrease in the anticipated 10-year lifespan of existing NTS solid waste disposal capacity.

4.2.1.3 Wastewater. Typical freshwater consumption in an industrial setting is approximately 40 gallons per employee per day (Clark, et al, 1971). This value has also been used to estimate wastewater production. The total amount of wastewater produced would be approximately 2,400 gallons per day at the site. An on-site septic system would be constructed to accommodate this wastewater.

4.2.1.4 Water Supply. The water supply for the construction and operation of the test site would increase withdrawal at NTS by approximately 3.7 million gallons per year (0.01 million gallons per day), a 0.5 percent increase in withdrawal. Because withdrawal from other wells on NTS is considerably larger than the Space Nuclear Thermal Propulsion (SNTTP) requirement, this

represents a small increase in demand on the water supply system. As discussed in Chapter 2, the exploratory well would need to be equipped with pumps, etc. to be converted to a production well. Also, a water supply pipeline connecting the well and SMTS would be required.

4.2.1.5 Mitigation Measures. Because impacts to infrastructure from SNTP program at SMTS are not anticipated, no mitigation measures would be required.

4.2.2 CTF

4.2.2.1 Energy. The INEL electrical distribution system is adequate to handle all PIPET and GTA test requirements due to the existing developed nature of the area. The SNTP requirement of 0.75 MW during tests would represent a 2.5 percent increase in peak demand at the Test Area North (TAN); average increase would be less than 1 percent. Mobile generators may be required to provide supplemental power during peak demands of the GTA testing operations.

4.2.2.2 Solid Waste. It is estimated that the amount of non-hazardous solid waste generated from this project would equal an average 175 tons per year over the life of the project.

At the INEL, use of the CFA landfill is anticipated to be terminated in 1995, at which time a new landfill is anticipated to be operational. Impacts to solid waste management from implementation of this action at the CTF are expected to be similar to those described for the NTS.

4.2.2.3 Wastewater. Typical freshwater consumption in an industrial setting is approximately 40 gallons per employee per day (Clark, et al, 1971). This value has also been used to estimate wastewater production. The total amount of wastewater produced would be approximately 2,400 gallons per day at the site.

The existing sewage system for the CTF consists of a series of evaporation ponds with a total holding capacity of approximately 16 million gallons. Present production of wastewater is approximately 8,000 gallons per day. The total amount of wastewater generated would be approximately 12,000 gallons per day at the site, well below the evaporative potential of the ponds.

4.2.2.4 Water Supply. The water supply for the construction and operation of the test site would represent 0.1 percent of the volume of water allocated to INEL. Because INEL uses a maximum of 12 percent of its allocation, this additional demand could easily be met.

4.4.2.5 Mitigation Measures. Because impacts to infrastructure from SNTP program activities at CTF are not anticipated, no mitigation measures would be required.

4.2.3 No-Action Alternative

Because no construction would occur with the No-Action Alternative, no impacts to infrastructure would occur at either of the SNTP alternative sites.

4.3 LAND USE

4.3.1 SMTS

There would be no land use impacts at the SMTS. The change in land use at the SMTS from an unoccupied area to 100 acres of facilities for the proposed use as a nuclear propulsion test site is consistent with the NTS mission. The SMTS is sufficiently removed from other testing areas to preclude interference with underground testing and other NTS activities.

Construction of the PBR validation test facility would not result in any land use conflicts to adjoining areas as a result of construction of the facility. There is sufficient area for the establishment of safety buffer zones around the site.

Because impacts to land use from SNTP program activities at the SMTS are not anticipated, no mitigation measures would be required.

4.3.2 CTF

The change in land use from CTF activities to PBR validation testing would be compatible with other similar research and development operations at INEL. However, it may cause restrictions on future use of adjacent facilities.

The land area that would be affected at the CTF site already has existing facilities which would be modified; additional expansion of less than 50 acres would also be required for a total project site of approximately 100 acres. The additional facilities and related safety buffer zones in the expanded area would not impact other land uses in the vicinity. Due to PBR testing activities, restrictions on grazing in the vicinity of the site may occur on an increasing basis.

Because impacts to land use from SNTP program activities at the CTF would be minor, no mitigation measures would be required.

4.3.3 No-Action Alternative

Because no facility construction or renovation/modification of existing facilities would occur with the No-Action Alternative, no impacts to land use would occur at either of the SNTP alternative sites.

4.4 TRANSPORTATION

4.4.1 SMTS

4.4.1.1 Transportation. The transportation of construction and operations personnel to SMTS would increase the one-way daily peak hour traffic on U.S. 95 from Las Vegas by a maximum of 100 vehicles during construction, and 60 vehicles during operations. Because some employees would use car pools or buses, the actual increase in vehicles would probably be somewhat lower. The total traffic volume on U.S. 95 would increase by about 5.9 percent (average annual daily traffic [AADT] 3,600) during the construction phase, and by about 3.5 percent over baseline conditions, to 3,520 AADT during the operations phase. Because this segment of U.S. 95 is a four lane divided highway, no adverse affects are expected from the increased traffic volume. As discussed in Chapter 2, Mine Mountain Road and Saddle Mountain road would be improved to accommodate truck and operations traffic to the SMTS. Other existing NTS roads would not be adversely affected by the increased traffic volume.

4.4.1.2 Airspace. Due to the airspace restrictions in place at NTS, no aircraft are likely to be in the vicinity of the PBR validation test facility during operations. A Notice to Airmen can be issued in advance, advising pilots of the testing operations to ensure that inadvertent flights do not occur during these periods.

Mitigation Measures

Because adverse impacts to traffic to and from the SMTS site are not expected to result from SNTP program activities, no mitigation measures would be required.

No special mitigation measures would be required to restrict airspace during testing operations beyond the existing controls and notification procedures.

4.4.2 CTF

4.4.2.1 Transportation. During peak construction, a maximum of 100 workers would be commuting to the CTF site at INEL. A maximum of 60 workers would be commuting during the operations phase. The majority of these workers would be commuting from Idaho Falls, with smaller numbers commuting from other communities. The use of buses for transporting

personnel from population centers to the sites at INEL is expected to continue, which would minimize increases in traffic volume resulting from SNTP operations.

Assuming that approximately 80 percent of workers would travel to INEL by bus on Idaho State Route 33, traffic during the construction phase would increase by about 4 percent, to about 552 AADT. Operations traffic would increase the traffic volume on State Route 33 by less than 3 percent. No reduction in level of service on State Route 33 would be expected during the operations phase. No SNTP traffic is expected to access the CTF using either U.S. 20 or 26.

PBR validation test activities may require the closure of State Highways 33, 28 or 22 for durations of less than 1 hour. Traffic would be rerouted to the two open highways. This would add approximately 11 to 22 miles to traffic traversing the INEL, depending on which highway was closed. Closure agreements would be negotiated with the State of Idaho Transportation Department. The arrangements for such closures at the INEL would be prepared by the INEL security force (Protection Technology of Idaho) in conjunction with the test facility operating contractors security department.

Roads within INEL operate below capacity, and would be able to absorb traffic generated by the SNTP program.

4.4.2.2 Airspace. During test operations, the flaring of hydrogen would cause thermal heating to a height of several thousand feet. Currently, flights below 1,600 feet above ground level are restricted. This is not sufficient to preclude interference between the thermal plume during testing and flights over the test area.

Mitigation Measures

Added traffic and road closures would not result in increased environmental impacts, therefore mitigation measures would not be required.

In addition to the existing controls and notification procedures, special mitigation measures would probably need to be developed to restrict airspace during testing operations.

4.4.3 No-Action Alternative

If the SNTP program were not implemented, traffic in the vicinity of NTS or INEL would not increase as a result of program activities; neither would there be any need for changes to existing airspace restrictions. Conditions would be similar to the baseline conditions for transportation as described in Chapter 3.

4.5 HAZARDOUS MATERIALS/WASTE MANAGEMENT

This section addresses the potential for environmental impacts caused by hazardous materials/waste management practices associated with the use of SMTS and CTF, and the potential impacts of existing contaminated sites.

Because SNTP operations at the selected PBR validation test facility would be the same at both alternative locations, the amounts and types of radioactive and non-radioactive hazardous wastes generated are expected to be the same.

4.5.1 SMTS

4.5.1.1 Hazardous Materials. Transporting fresh non-irradiated nuclear fuel over the nation's roadways occurs utilizing Safe, Secure Transports or other approved packaging/vehicle systems that comply with Department of Energy (DOE), Department of Transportation (DOT), and Nuclear Regulatory Commission (NRC) safety and safeguards requirements (NRC, 1977, Final EIS on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170). The transport vehicles are designed to provide sufficient safeguards to protect uranium-235 (U-235) while enroute between secure facilities. Shipments are traced by an operations center located in Albuquerque, New Mexico, and escorted continuously whenever they are outside the boundaries of a secure facility.

The largest quantity of fuel material to be transported in a single shipment to support the PBR validation testing program involves transporting the reactor cores. All proposed shipments consist entirely of fresh, non-irradiated uranium fuel which results in negligible radiation exposures both at the surface of the transportation trailer and within the driver's compartment. Radiation surveys at the point of origin would demonstrate that spreadable contamination levels are negligible. A criticality analysis would be performed to assure compliance with DOT and NRC transport requirements. This ensures that no credible scenario could cause the material to be repositioned into a critical mass during normal transport or a hypothetical accident. All shipments would comply with the requirements of DOT regulations.

Transportation of specimens for post-irradiation examination is routine between test reactors and laboratories. Existing DOT approved procedures would be used. All shipments within NTS of radioactive materials including U-235 would be accomplished in accordance with the specific requirements at NTS and in compliance with DOE Orders. Arrangements would be made through the respective installation Operations and Maintenance contractor.

4.5.1.2 Nonradioactive Hazardous Waste. The quantity of nonradioactive hazardous waste anticipated to be generated during the validation testing

activities is estimated to be approximately 500 cubic feet (seventy 55-gallon drums) over the life of the program. A waste minimization program, would be implemented to limit the generation of hazardous waste. Procedures would include product substitution when possible to reduce the quantity of solvents used in support of test activities. Hazardous wastes generated as a result of operations would be stored temporarily at the test facility. All waste will be labeled and shipped to an Environmental Protection Agency-approved Treatment, Storage and Disposal facility.

4.5.1.3 Radioactive Hazardous Waste. All radioactive waste materials are classified as defense wastes and managed in accordance with DOE Order 5820.2A (Radioactive Waste Management). Radioactive wastes most likely to be generated would be low-level waste (LLW) and mixed waste. Additionally, there is potential that transuranic (TRU) waste may be generated.

Low-Level Radioactive Solid Waste

It is anticipated that the low-level radioactive solid waste generated at the SMTS would be 1.6 million cubic feet over the life of the project. LLW requiring disposal would consist of solid wastes from the handling, cleaning, and disassembling of the canister assemblies, contaminants removed directly from the effluent stream, and the ETS components, and materials from decontaminating the facility at the end of the program. This material would be placed in an NTS Radioactive Waste Management Site (RWMS).

In addition, the irradiated fuels and irradiated test specimens determined by DOE to be low-level wastes would be disposed of as such. These wastes would be appropriately packaged, nondestructively assayed, and disposed of at one of the existing RWMS located in Area 5 of the NTS.

NTS presently has a remaining capacity of 17.7 million cubic feet for solid low-level radioactive waste with an anticipated annual input of 880,000 cubic feet. The SNTP LLW would add 18 percent to this annual input for 10 years. At the end of the 10 year life of the SNTP program, the remaining capacity at NTS would be 7.6 million cubic feet. The NTS would still have 8.6 years of operating capacity remaining. However, NTS is continually updating its solid LLW storage and disposal capacity requirements. Expansion of waste storage and disposal facilities is an ongoing process to meet the waste management mission of disposing of all waste. The solid LLW generated as a result of the SNTP facility would cause no changes in this operational arrangement.

Mixed Waste

Some mixed waste may be generated during program activities. This would include low-level radioactive materials contaminated by solvents or solvent

residues. It is anticipated that no more than 70 cubic feet of that material (which could be contained in ten 55-gallon drums) would be produced annually by program activities.

Mixed wastes would be contained at their point of generation and characterized for eventual compliance with Land Disposal Restrictions (LDR) and the installation waste disposal requirements. Containers would be transported to a mixed waste (Resource Conservation and Recovery Act) disposal area at the RWMS (DOE, 1990c). Mixed wastes must meet LDR requirements prior to disposal. Every effort would be made to minimize or totally eliminate quantities of mixed wastes generated by the SMTS projects.

NTS presently has a remaining capacity of 5 million cubic feet for mixed radioactive waste (DOE, 1990c) with an anticipated annual input of 700,000 cubic feet from approved DOE generators. The maximum anticipated annual input of mixed wastes from the SNTP program (70 cubic feet) is only 0.01 percent of the anticipated annual mixed waste input at NTS.

TRU

PBR validation test activities may generate minimal quantities of TRU waste. The only facility operation that could potentially generate TRU waste is cleanup of the ETS, due to the accumulation of actinides (radioactive elements with atomic numbers ranging from 89 through 103) during several test operations. On-site generated wastes properly certified as TRU would be packaged and stored at the NTS pending later shipment to either the Waste Isolation Pilot Plant (WIPP) or another designated facility capable of providing permanent disposal for TRU wastes. The handling of any program-generated TRU wastes would cause no changes to the existing operational arrangements at the NTS and represents only a very small portion of the NTS TRU waste shipment and disposal activities as analyzed in the WIPP Final EIS (DOE, 1980).

4.5.1.4 Environmental Restoration. Implementation of the SNTP program at the SMTS would not impact any NTS environmental restoration programs.

4.5.1.5 Mitigation Measures. Mitigation measures to reduce the impacts from PBR validation activities on the environment would include:

- Implementation of a minimization program to limit the generation of non-radioactive hazardous waste (solvents)
- Adherence to the in-place volume reduction program to reduce the amount of solid LLW
- Increasing the LLW storage and disposal capacity.

4.5.2 CTF

4.5.2.1 Hazardous Materials. The impacts associated with transporting U-235 for the SNTP program at CTF are identical to those described for SMTS (see Section 4.5.1.1).

4.5.2.2 Nonradioactive Hazardous Waste. The quantity of nonradioactive waste generated at the CTF is the same as for the SMTS. Similar management procedures will be followed, including implementation of a waste minimization program and final disposition to an EPA approved Treatment, Storage and Disposal Facility (see Section 4.5.1.2).

4.5.2.3 Radioactive Hazardous Waste. Radioactive waste generated would be LLW, mixed waste and possible TRU as described for the SMTS (see Section 4.5.1.3).

Low-Level Radioactive Solid Waste

At the INEL, LLW is disposed in the Subsurface Disposal Area located at the RWMC. Prior to disposal, waste is packed in drums or LLW crates and nondestructively assayed.

INEL presently has a remaining capacity of 3.5 million cubic feet for low-level radioactive solid waste with an anticipated annual input of 102,000 cubic feet. The SNTP program would contribute approximately 1.6 million cubic feet over a 10 year period, requiring 46 percent of available capacity. This contribution would represent a 157 percent annual increase in LLW at INEL. At the end of the 10 year life of the SNTP program, the remaining capacity at INEL would be 0.9 million cubic feet or 26 percent of current capacity. The INEL would then have approximately 9 years of operational capacity for LLW. An in-place volume reduction program would reduce the input of solid LLW. Although the solid LLW generated would cause no changes in the operational arrangement, it would represent 61 percent of the total INEL solid LLW input through the life of the project.

Mixed Waste

Some mixed waste may be generated during program activities. This would include low-level radioactive materials contaminated by solvents or solvent residues. It is anticipated that no more than 70 cubic feet of that material would be produced by program activities annually.

INEL presently has a baseline capacity of 2,800 cubic feet for mixed radioactive waste in interim storage. Certain quantities would be removed so that the overall capacity would not be filled (Nelson, 1991a). Current annual input is 420 cubic feet. The anticipated annual input of mixed

wastes from the SNTP program (70 cubic feet) represents a 6 percent increase in the annual input of mixed waste, and is only 2.5 percent of the capacity for mixed waste at INEL. Mixed wastes are presently stored on site at the INEL, awaiting an RCRA-permitted facility for disposal.

TRU

Any TRU waste generated during PBR validation test activities at the GTF site would be certified according to WIPP waste acceptance criteria, packaged, and stored, pending shipment to the WIPP or another designated facility for disposal. The handling of any program-generated TRU wastes would cause no changes to the existing operational arrangements at INEL and represents only a very small portion of the INEL TRU waste shipment and disposal activities.

4.5.2.4 Environmental Restoration. PBR validation test activities will not impact the ongoing groundwater cleanup at TAN or any other environmental restoration programs at INEL.

4.5.2.5 Mitigation Measures. Mitigation measures to reduce the impact from SNTP activities to the environment are the same as for SMTS.

4.5.3 No-Action Alternative

Because no new construction, facility modification, hazardous material use, or hazardous waste generation activities would occur with the No-Action Alternative, no impacts to the environment would occur at either of the SNTP alternative sites.

4.6 AIR QUALITY

Construction and operation of the proposed field test facility, regardless of the selected location, would produce small amounts of air pollution from the combustion of fossil fuels from mobile sources and for power generation. Fugitive dust emissions would be expected during construction and earth-moving activities.

4.6.1 SMTS

At the SMTS, it would be necessary to perform several activities during the construction phase of the project that could potentially impact air quality. Fugitive dust (particulate matter less than 10 microns in diameter [PM_{10}]) emissions would be generated from the 100 acres of land cleared for PBR validation testing. In addition, 2 acres would be cleared for associated infrastructure (water and power) support and from errant vehicles crossing into previously undisturbed areas. PM_{10} emissions are a function of the amount of land cleared, the time of exposure, soil type and moisture, and

windspeed. Elevated PM_{10} concentrations would tend to fall off rapidly from the source with distance. Left uncontrolled, dust and the associated PM_{10} emissions would continue to blow off of graded surfaces indefinitely. Approximately 4 acres of land surrounding the facility fence (used for a fire break) would be a long term source of PM_{10} , if not mitigated. Additional emissions anticipated from construction include exhausts from vehicles and equipment used during site development. Exhaust emissions associated with construction amount to a very minor, short term component of the regional air pollutant inventory.

Emissions from the operational phase of the project would be related to vehicle traffic (including commuter traffic) and minor site activities, including the intermittent use of diesel power generators and sources which contribute to the volatile organic compound emission inventory. If portable generators larger than 500 brake-horsepower are required for this activity, air emission permits, issued by the state of Nevada, would be required prior to their use. Stationary generators (i.e., in place longer than 1 year) larger than 250 brake-horsepower require Nevada air emission permits. The flare stack associated with the operational phase is not anticipated to produce any measurable emissions. After flaring, the primary components (over 98 percent) are nitrogen, water vapor, oxygen, and hydrogen. Because tests would be infrequent and of short duration, and because these flare stack emissions are components of air that are not regulated by air quality laws or regulations, operations emissions are not expected to add substantially to the regional air pollutant inventory.

Because the dispersion of atmospheric components at the NTS is good, and the amount of pollutant emissions associated with this alternative are minor, the impact on the regional and local air quality from this alternative would be negligible.

4.6.1.1 Mitigation Measures. Although the impacts from construction activities (land clearing and associated vehicle and equipment emissions) are slight, the following mitigation measures would further reduce the potential for dust and exhaust emissions at the site:

- Minimize the length of time fresh soil surfaces are left exposed
- Periodically spray exposed surfaces with water or a soil binder
- Minimize the extent of ground disturbance to that necessary to accomplish the project
- Delay ground disturbance activities during periods of high winds
- Perform revegetation and/or restabilization of disturbed areas upon completion of construction activities. This may include paving or graveling of exposed soils

- Maintain exhaust systems on construction equipment and vehicles at the proper operating levels.

Operational emissions may be reduced by encouraging the use of carpools and buses to the site by commuting employees. While on the site proper, employees could be encouraged to walk or use bicycles for transportation. Additional mitigation includes the maintenance of equipment (i.e., generators, tanks) in order to minimize emissions from these sources.

4.6.2 CTF

At the CTF, it would be necessary to perform several activities during the construction phase of the project that could potentially impact air quality. Fugitive dust (PM_{10}) emissions would be generated from the 55 acres of land cleared for PBR validation testing. PM_{10} emissions are a function of the amount of land cleared, the time of exposure, soil type and moisture, and windspeed. Elevated PM_{10} concentrations would tend to fall off rapidly from the source with distance. Left uncontrolled, dust and the associated PM_{10} emissions would continue to blow off of graded surfaces indefinitely. Additional emissions anticipated from construction include exhausts from vehicles and equipment used during site development. Exhaust emissions associated with construction amount to a very minor, short term component of the regional air pollutant inventory.

Emissions from the operational phase of the project would be related to vehicle traffic (including commuter traffic) and minor site activities (including volatile organic compound emissions from various sources). The flare stack associated with the operational phase is not anticipated to produce any measurable emissions. After flaring, the primary components (over 98 percent) are nitrogen, water vapor, oxygen, and hydrogen, all of which are components of air that are not regulated by air quality laws or regulations. Test operations would be infrequent, of short duration, and are not expected to affect the attainment status of the region.

Because the dispersion of atmospheric components at the INEL is good, and the amount of pollutant emissions associated with this alternative are minor, the impact on the regional and local air quality from this alternative would be negligible.

4.6.2.1 Mitigation Measures. Although the impacts from construction activities (land clearing and associated vehicle and equipment emissions) are slight, the mitigation measures discussed in Section 4.6.1.1 would further reduce the potential for dust and exhaust emissions at the site.

Operational emissions may be reduced by encouraging the use of carpools and buses to the site by commuting employees. While on the site proper, employees could be encouraged to walk or use bicycles for transportation.

Additional mitigation includes the maintenance of equipment (i.e., tanks) in order to minimize emissions from these sources.

4.6.3 No-Action Alternative

Because no construction or PBR validation test operations would occur with the No-Action Alternative, no impacts to air quality would occur.

4.7 BIOLOGICAL RESOURCES

Implementation of the Proposed Action at the two alternative sites could potentially affect biological resources through alteration or loss of vegetation and wildlife habitat. These impacts are described below for each alternative.

4.7.1 SMTS

Construction of the PBR validation test facility at SMTS would affect biological resources primarily through the loss of vegetation and wildlife habitat. Noise during operation of the facility would temporarily frighten off some wildlife species and thermal heating from the flaring of hydrogen gas might kill birds flying nearby.

4.7.1.1 Vegetation. The construction of the validation test facility would result in the loss of approximately 100 acres of land from the Transitional Desert Association habitat. This vegetation community is common, and no sensitive, threatened, or endangered species are found at the site. An area of 4 acres surrounding the test facility fence would have all vegetation removed to act as a fire break. Brush fires are a major risk to programs at NTS and have accounted for plant cover modification of sizeable areas.

Construction of the test facility, improvement of the access road, and installation of the required electrical transmission line and water system would impact up to 1,000 Joshua trees (EG&G, 1992). Joshua trees are not listed as threatened or endangered by either the state or federal governments and do not require mitigation measures for their removal.

4.7.1.2 Wildlife. Noise from the validation tests are expected to reach approximately 125 adjusted decibels (dBA) and would affect the nearby animal populations, principally birds commonly found in the area, such as the black-throated sparrow and Le Conte's thrasher. Birds would be frightened off temporarily at the beginning of testing activities, but are expected to return upon completion of each test. The noise from the flare stack may scare away birds that might otherwise fly into the flare during flaring operations. Other animals, such as rodents and other small mammals and reptiles, may be frightened off by the test noise.

The flaring of hydrogen from the effluent treatment system would cause thermal heating of approximately 810 degrees Kelvin (K) (540° Centigrade [c]) to a height of several hundred feet. In addition, the flame from hydrogen is not visible during the daytime unless treated with a chemical to provide color. The flare during those tests would kill any birds flying into it. As noted earlier, noise from the flaring may serve to scare away birds that might fly over the flare stack.

4.7.1.3 Threatened and Endangered Species. Based on existing data and the survey of the SMTS and its new power line route, no federally listed threatened or endangered species, or their habitat, are known to occur at SMTS.

4.7.1.4 Sensitive Habitats. The only known sensitive habitat in the vicinity of SMTS is a potential wetland, Yucca Flats (Dry) Lake, located eight miles east of SMTS. Construction and operational activities at the SMTS would be localized to the Saddle Mountain area and would not impact this potential wetland.

4.7.1.5 Mitigation Measures. Because no impacts to sensitive habitats or threatened or endangered species will occur, no mitigation measures are required.

4.7.2 CTF

Construction of the PBR validation test facility at CTF would result in only minor impacts to biological resources because of the developed nature of TAN.

4.7.2.1 Vegetation. Because of the existing developed nature of TAN in general and the CTF site in particular, modifications to existing facilities and construction of the test facility would affect less than 50 acres of previously disturbed land adjacent to the containment structure. The highly disturbed nature of the land in the vicinity has resulted in low quality habitat.

4.7.2.2 Wildlife. The same activities that impact wildlife during operations at NTS would also occur at CTF. Birds and other small animals would be frightened away temporarily due to noise from the validation test facility. Birds flying into the flare would be killed, however, this is expected to happen only rarely. However, due to previous disturbances to vegetation, the existing developed nature of the facility, and the limited wildlife habitat present, impacts associated with construction of the facility and with test operations would be less than for newly constructed sites.

4.7.2.3 Threatened and Endangered Species. The bald eagle has been observed in the past in the northern portions of INEL, with several individuals roosting at Little Lost River approximately 12 miles west of CTF.

and foraging near the mountains north and west of INEL. No impacts to this endangered species are expected if SNTP test facilities are located at CTF.

4.7.2.4 Sensitive Habitats. Because there are no surface water resources in the vicinity of CTF, the construction and operation of the facility would not have any impacts on sensitive habitats.

4.7.2.5 Mitigation Measures. Because no impacts to sensitive habitats or threatened or endangered species will occur, no mitigation measures are required.

4.7.3 No-Action Alternative

Because no construction, facility modification, or test operations would occur with the No-Action Alternative, no impacts to biological resources would occur at either of the SNTP alternative sites.

4.8 CULTURAL RESOURCES

Potential impacts to cultural resources were assessed by (1) identifying the type and location of activity that could directly or indirectly affect cultural resources, (2) determining the nature and potential significance of cultural resources in potentially affected areas, and (3) classifying potential effects as adverse or not adverse.

As outlined by the regulations implementing Section 106 of the National Historic Preservation Act (36 Code of Federal Regulations [CFR] Part 800.9) program activities can have an adverse effect on a historic property when that effect may alter the characteristics that qualify it for inclusion in the National Register. Adverse effects include but are not limited to:

- Physical destruction, damage, or alteration of all or part of the property
- Isolation of the property from or alteration of the character of the property's setting when that character contributes to the property's qualification for the National Register
- Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting
- Neglect of a property resulting in its deterioration or destruction
- Transfer, lease, or sale of the property.

Effects that would otherwise be found to be adverse may be considered as being not adverse for the purpose of Section 106 when:

- The historic property is of value only for its potential contribution to archaeological, historical, or architectural research, and when such value can be substantially preserved through the conduct of appropriate research, and such research is conducted in accordance with applicable professional standards and guidelines.
- The undertaking is limited to the rehabilitation of buildings and structures and is conducted in a manner that preserves the historical and architectural value of affected historic property through conformance with the Secretary's "Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings."
- The undertaking is limited to the transfer, lease, or sale of a historic property, and adequate restrictions or conditions are included to ensure preservation of the property's significant historic features.

4.8.1 SMTS

4.8.1.1 Archaeological Resources. During the cultural resources surveys at the SMTS, seven prehistoric archaeological sites were identified within the region of influence at SMTS (see site descriptions in Section 3.8.1). Five of the sites were collected and the remaining two sites are isolated finds; none of the sites are considered significant under National Register criteria and State Historic Preservation Officer (SHPO) concurrence has been received (Appendix G). Because of these findings, no adverse impacts are expected to occur to archaeological resources if the SMTS alternative is chosen for SNTP activities.

4.8.1.2 Historic Resources and Structures. Because no historic resources or structures have been identified within the region of influence for activities at SMTS, no impacts are expected to occur.

4.8.1.3 Native American Resources. Because no Native American resources have been identified within the region of influence for the SMTS site, no impacts are expected to occur.

4.8.1.4 Paleontological Resources. Because no paleontological resources have been identified within the region of influence for the SMTS site, no impacts are expected to occur.

4.8.1.5 Mitigation Measures. Although the known archaeological resources located within the SMTS region of influence are not considered significant, the presence of sites does indicate some potential for cultural resources to be discovered during the course of project activities. In the event that

archaeological, historic, paleontological, or Native American resources are discovered, ground disturbing activities would cease in the immediate area and a qualified archaeologist would be notified; all subsequent actions would comply with 36 CFR Part 800.11 and the Native American Graves Protection and Repatriation Act.

4.8.2 CTF

4.8.2.1 Archaeological Resources. Two prehistoric archaeological sites (one sparse lithic scatter and one isolated activity area) have the potential to be affected by SNTP Program activities at the CTF site. Neither of these sites is considered significant under National Register criteria and all of the previous surveys of the TAN and CTF area indicate a low probability for encountering additional cultural resources (Idaho State University, 1986). Consultation with INEL's cultural resources contractor, EG&G, confirmed that no further archaeological surveys would be required for SNTP Program activities at the CTF site; Idaho SHPO concurrence has been received (Appendix G). Because of these findings, no adverse impacts are expected to occur to archaeological resources if the CTF alternative is chosen for SNTP activities.

4.8.2.2 Historic Resources and Structures. Historically, many INEL facilities have been considered unique because of the nature of the activities associated with them. As described in Section 3.8.2, the CTF is the only nuclear reactor test facility of its size in the world designed to simulate all of the important events that could occur in a commercial pressurized water reactor power plant. Although the reactor has been removed and the building is currently undergoing asbestos abatement, it continues to retain the qualities that would make it potentially eligible for the National Register (U.S. Department of the Interior, 1991; Advisory Council on Historic Preservation, 1991). Consultation between the Idaho SHPO, the Advisory Council on Historic Preservation, and INEL's cultural resources contractor, EG&G, Idaho, Inc., is addressing the issue of National Register eligibility for several INEL properties, recognizing that they have not yet attained the age of 50 years, but demonstrate exceptional scientific and engineering significance for having played a major role in the development of nuclear science; a programmatic agreement to outline various mitigative requirements is currently being outlined (Appendix G).

Until the consultation process determines the eligibility of the CTF for the National Register, it will be considered a potentially significant historic resource and, as such, modifications proposed by the SNTP program could have an adverse effect. Typical mitigation measures developed during consultation would ensure that the historic significance of the CTF is documented, including compiling and archiving engineering drawings and photographic and narrative documentation. If the CTF is determined not

eligible for the National Register, no effect would occur from proposed modifications.

4.8.2.3 Native American Resources. Because no Native American resources have been identified within the region of influence for the CTF alternative, no adverse impacts are expected to occur.

4.8.2.4 Paleontological Resources. Because no paleontological resources have been identified within the region of influence for the CTF alternative, no adverse impacts are expected to occur.

4.8.2.5 Mitigation Measures. Although the known archaeological resources located within the CTF region of influence are not considered significant and the probability for additional sites is low, the presence of sites does indicate some potential for cultural resources to be discovered during the course of project activities. In the event that archaeological, paleontological, or Native American resources are discovered, ground disturbing activities would cease in the immediate area and a qualified archaeologist would be notified; all subsequent actions would comply with 36 CFR Part 800.11 and the Native American Graves Protection and Repatriation Act.

The consultation process currently in progress (identified in Section 4.8.2.2) is expected to outline mitigative measures for the treatment of historic resources and structures on the INEL that may be subject to adverse effects from program activities. Mitigation measures developed during consultation would ensure that the historic significance of the CTF is documented and would include compiling and archiving engineering drawings and photographic and narrative documentation if determined to be a significant historic resource.

4.8.3 No-Action Alternative

Because no ground disturbing activities or facility modifications would occur with the No-Action Alternative, no impacts to cultural resources would occur at either of the two SNTP alternative sites.

4.9 GEOLOGY AND SOILS

4.9.1 SMTS

4.9.1.1 Physiography and Geology. Construction of the PBR validation test facility would require no more than 100 acres of land; grading and site preparation (cut and fill) requirements are approximately 26,000 and 37,000 cubic yards, respectively. Fill material would be extracted from a borrow area on the NTS and the excavated material from road construction would be deposited on the downhill side or utilized for fill within the test facility.

Alterations to the natural drainage could occur as a result of grading. Culverts would be designed into the surface drainage system for ramps and road crossings. Runoff from heavy precipitation may fill adjacent dry washes, but would not flood the facility because of its location on a interchannel topographic high, and other construction designs to prevent flooding of operations areas. Because the SMTS would be built to be compatible with existing topographic contours and facility size would be minimized where possible, little change would be made to the natural terrain.

4.9.1.2 Seismic and Volcanic Activity. The SMTS has a potential for moderate damage from seismic activity. The SMTS area is also exposed to some ground motion and shock waves from underground testing of nuclear explosions. As a safety precaution, and due to the activity induced by underground testing, all structures at the NTS are required to conform to UBC Seismic Zone 4 (greatest seismic risk zone) construction requirements and these requirements have been incorporated into facility and infrastructure designs for the SMTS. Because of this design requirement, no impacts are expected.

Because no volcanic eruptions have been reported during historic times, the potential for impacts to SNTP program activities over the 10-year life of the program from volcanic activity would be remote. Current studies being conducted in Crater Valley, approximately 23 miles south-southeast of SMTS, on eruptions from existing cinder cones indicate the last eruptions occurred approximately 10,000 to 20,000 years ago.

4.9.1.3 Soils. Construction activities at the SMTS would involve leveling and/or resurfacing of soils on approximately 100 acres. Although dust and soil would be transported by wind during these activities, effects are expected to be local and temporary. Removal of vegetation from the construction area would not significantly increase soil erosion because the area is sparsely vegetated and the ground surface is predominantly gravel. Therefore, wind effects and increases in soil erosion from rainfall are expected to be minimal. Protection against erosion would include:

- Orientation of the facility parallel to natural surface features to minimize water-induced erosion
- Orientation of the facility to minimize wind-induced erosion
- Application of water to minimize wind-induced erosion
- Revegetation of temporarily disturbed locations.

4.9.1.4 Mitigation Measures. Because measures to reduce the level of impacts to geology and soils such as those listed above would be

incorporated into the design and program plans for the Proposed Action at SMTS, no mitigation measures would be required.

4.9.2 CTF

4.9.2.1 Physiography and Geology. The expansion of the CTF facility would require the cutting and filling of about 3,000 and 4,000 cubic yards, respectively. Some alterations of the natural drainage could also occur as a result of grading. Because little change would be made to the character of the area, the modification of CTF would have a negligible impact on topography.

Because the proposed modification and operation of the test facility at CTF would cause no loss or irretrievable commitment of geological resources, the project would have a negligible impact on geology.

4.9.2.2 Seismic and Volcanic Activity. Due to the seismic character of the CTF area, no impacts related to earthquakes are expected.

Two major stages of volcanic activity (explosive and non-explosive) have occurred in the Eastern Snake River Plain over the past 15 million years. Non-explosive volcanism began about four million years ago and continued to as recently as 2,000 years ago, producing a series of overlapping basaltic flows from numerous local vents and small craters. Although there are two inactive volcanic craters within 6 miles of the CTF site and over time the INEL area has been volcanically active, there have been no eruptions or flows for over 2,000 years. Therefore, impacts related to volcanic activity are not expected.

4.9.2.3 Soils. Construction would cause some leveling or resurfacing of the soils on less than 50 acres. Dust and soil would be transported by winds during construction activities, but the effect would be local. Removal of vegetation from the construction area would not significantly increase soil erosion during rainfall since the vegetation is sparse. Protection against erosion would include:

- Orientation of any new facilities parallel to natural surface features to minimize drainage and erosion impacts
- Application of spray mist water to minimize wind-caused soil erosion
- Revegetation of temporarily disturbed areas.

4.9.2.4 Mitigation Measures. Because measures to reduce the level of impacts to geology and soils have been incorporated into the design and

program plans for the Proposed Action at CTF, no mitigation measures would be required.

4.9.3 No-Action Alternative

Because no construction would occur with the No-Action Alternative, no impacts to geology and soils would occur at either of the SNTP alternative sites.

4.10 NOISE

Noise sources associated with SNTP program activities primarily include those associated with equipment required for construction of the PBR validation test facility. These types of heavy equipment routinely generate noise levels of approximately 90 dBA. While actual noise limits vary depending on the total time of daily exposure, the Occupational Safety and Health Administration (OSHA) limit for an eight hour exposure is 90 dBA; the OSHA limit for 15 minutes or less is 115 dBA.

Testing activities are expected to generate noise levels of approximately 125 dBA for short infrequent periods but would be intermittent during the scheduled operational testing sequence.

4.10.1 SMTS

Construction noise would be monitored by the Safety Office at NTS and workers in the vicinity of the construction equipment would be required to wear appropriate hearing protection. Because a noise level of 90 dBA is attenuated to 60 dBA at a distance of 41 feet, the closest non-project related personnel on the NTS (located approximately 6 miles) away would not be impacted by construction noise. As well, the closest sensitive community receptors to the SMTS that could be affected by construction noise levels are located approximately 23 miles away and would likewise not be affected.

During test activities, all non-essential personnel would be restricted from the SMTS site during testing and relocated three miles away; operating personnel would remain in the control complex (which has been designed to provide a barrier to sound penetration) during testing activities.

Supplemental hearing protection inside the bunker would also be available. Because a noise level of 125 dBA is attenuated to 60 dBA at a distance of 2,326 feet, no non-project related NTS personnel or sensitive community receptors would be close enough to be adversely affected by SNTP testing activities.

Wildlife, principally birds, small mammals, and rodents, could be affected by the noise levels described for construction and testing activities; however,

these noise levels would be temporary and wildlife would be expected to return as they subside. Noise levels could provide a beneficial impact by scaring them away and preventing exposure to the emissions from the flare stack.

Mitigation measures at SMTS would include the following:

- OSHA-required hearing protection during construction activities when levels exceed 90 dBA
- Restriction of non-essential personnel from the ground test site during testing activities
- Protection of operational personnel in the control complex with supplemental hearing protection during activities.

4.10.2 CTF

Although less construction activity is anticipated at the CTF site, SNTP program activities would generate comparable noise levels during construction and testing activities as at SMTS. The nearest non-project related INEL personnel are located approximately 1.3 miles from the CTF site, and the nearest sensitive community receptors are located 11 miles away.

Mitigation measures at CTF would include the following:

- OSHA-required hearing protection during construction activities when levels exceed 90 dBA
- Restriction of non-essential personnel from the ground test site during testing activities
- Protection of operational personnel in the control complex with supplemental hearing protection during activities.

4.10.3 No-Action Alternative

Because no construction or facility modification would occur with the No-Action Alternative, no noise impacts would occur at either of the SNTP alternative sites.

4.11 WATER RESOURCES

4.11.1 SMTS

4.11.1.1 Groundwater. Groundwater in the area of the test site is 1,650 feet below ground surface in a tuffaceous aquifer. During SNTP construction operations, an average 3.7 million gallons of groundwater would be extracted per year. This demand, in addition to existing water withdrawal, is not expected to cause a measurable drawdown of the existing water table.

4.11.1.2 Surface Water. There are no surface water resources in the vicinity of the SMTS, and therefore, no impacts are projected.

4.11.1.3 Water Quality. Domestic wastewater products (sanitary sewage) would be delivered to a septic system. Groundwater is of sufficient depth that the possibility of adversely affecting its quality from this system would be negligible. Other wastewater from the receiving/assembly and disassembly buildings would be collected and disposed as hazardous waste.

Accidental spills of hazardous materials are not likely to affect the groundwater because of the extreme depth to groundwater (over 1,600 feet).

4.11.1.4 Mitigation Measures. Because no impacts to water resources would result from PBR validation test facility activities, no mitigation measures would be required.

4.11.2 CTF

One-half trillion gallons of water is withdrawn annually by all users from the Snake River Plain Aquifer, most of which is used for agriculture.

The DOE Idaho Operations Office has negotiated with the Idaho Department of Water Resources regarding a claimed water right for no more than 11 billion gallons annual withdrawal capacity under the Federal Reserve Doctrine. The state of Idaho has signed a Settlement Agreement and there have been public hearings. Based on these hearings, an Interlocutory Order will be generated. The INEL will abide by this order as it affects water use until the adjudication process is complete (DOE, 1991a).

4.11.2.1 Groundwater. The volume of water to be used during construction of the PBR validation test facility is approximately 2 million gallons and would be supplied from the in-place water supply system. This use of 2 million gallons would be a negligible increase in total use in the area (a very small fraction of the percent of total use). Construction water use represents about 1 gallon for every 1 million gallons

of the annual discharge of the aquifer to the Snake River and about 1 gallon for every 300,000 gallons of the volume withdrawn by all users of the eastern Snake River Plain. Proposed construction (2 million gallons) and annual SNTP program water use (3 million gallons per year) would represent much less than 0.1 percent of the volume negotiated in the water rights agreement with the Idaho Department of Water Resources.

4.11.2.2 Surface Water. Surface water resources in the vicinity of CTF include intermittent flows in Birch Creek and Big Lost River, however, no surface water withdrawal or discharges would occur during test facility construction. Because the PBR validation test activities would cause no measurable change in the projected baseline water resource system, the impacts of water use on water resources would be negligible.

4.11.2.3 Water Quality. Domestic waste would be handled by an existing sewage system. Spills of hazardous substances could introduce pollutants to the groundwater table but because of the depth to the water table, the potential for seepage into the groundwater is minimal. Due to the lack of surface waters that would be affected and the depth of the water table, the impacts of wastewater on groundwater resources would be minor.

4.11.2.4 Mitigation Measures. Because no impacts to water resources would result from PBR validation test facility activities, no mitigation measures would be required.

4.11.3 No-Action Alternative

Because no construction or facility modification would occur with the No-Action Alternative, no impacts to water resources would occur at either of the SNTP alternative sites.

4.12 HEALTH AND SAFETY

Section 4.12.1 presents the safety analysis and mitigation process which will be applied to this program. Section 4.12.2 presents the regulatory requirements which apply to radioactive exposure and the potential impacts associated with this test program. Computer modeling techniques are used to develop and analyze the potential radiation exposures produced by normal operations of the test reactor and transportation of radioactive materials. Similar computer modeling studies are presented for bounding case reactor and identifiable transportation accidents. Results of these studies indicate that applicable regulatory limits are never exceeded either during normal operations, or as a result of credible accidents, and the proposed validation test program poses no adverse risk to individuals in the vicinity of NTS and INEL, and along possible transportation routes.

For normal operations (i.e., no accidents), a regulatory standard applicable to public exposures (National Emissions Standards for Hazardous Air Pollutants [NESHAP]) of 10 millirems (mrem) annual exposure to the highest exposed individual is established by the Environmental Protection Agency (EPA). The SNTP program goal is 20 percent of this standard, or 2 mrem per year. Using a set of "model operating conditions" for weather, and the number of operations expected in a maximum-case year, modeling of bounding case normal operations yields the following maximum potential exposures:

- NTS: 0.6 mrem
- INEL: 1.35 mrem

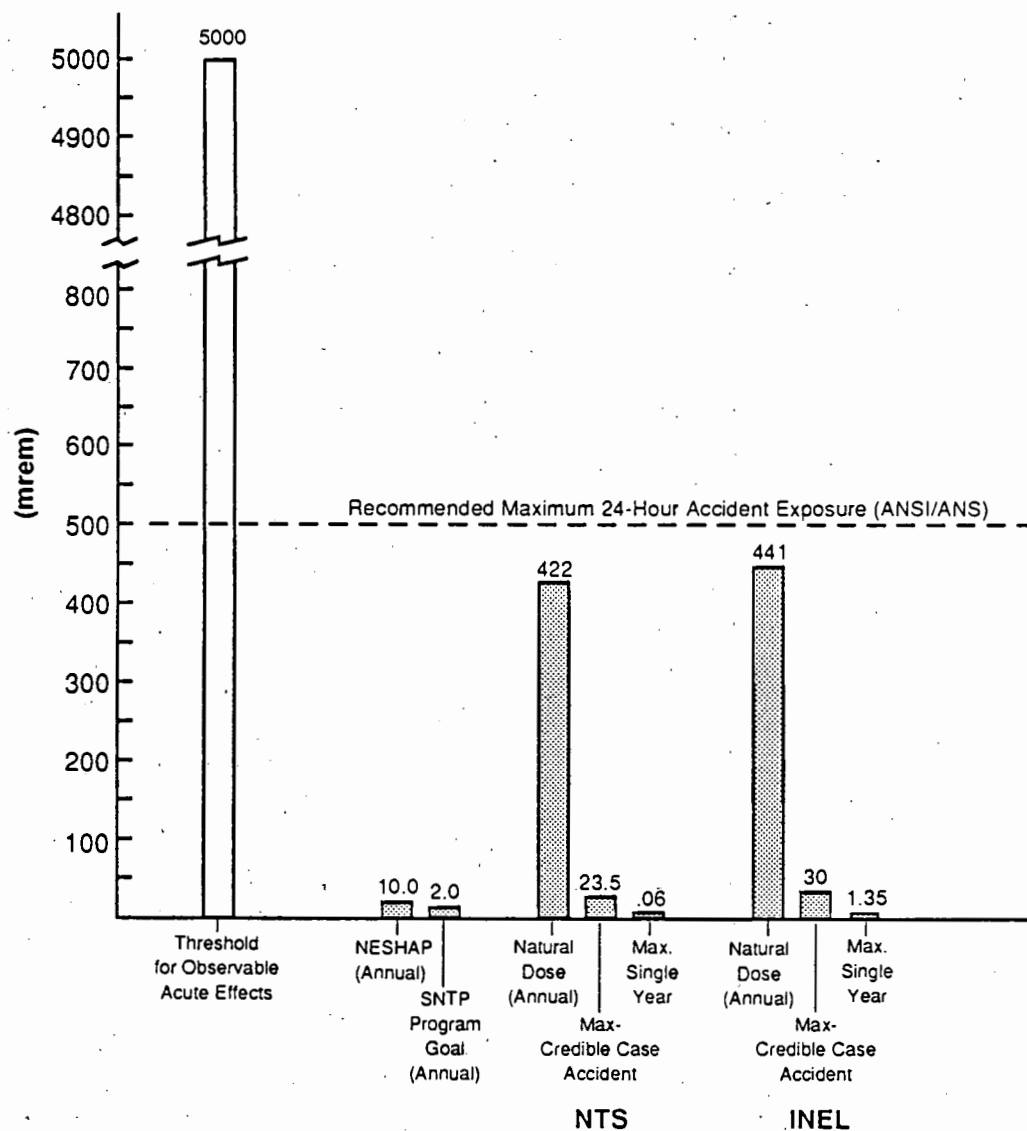
These values are well below both the regulatory standard and the PBR technology validation program goal. Even routine medical procedures such as a single chest X ray (2 mrem) results in larger exposures than are projected for this program (Greaney, 1992).

For accidents, a design limit of 500 mrem for a single, accidental, 24-hour exposure has been established based upon guidance in American National Standards Institute/American Nuclear Society (ANSI/ANS) Report 15.7. The bounding accident involves discharging a PBR Integral Performance Element Test (PIPET) core into an Effluent Treatment System (ETS) followed by the failure of the most critical ETS component (i.e., the component whose failure could result in the greatest off-station impact). This scenario assumes that, at the time of core failure, the core contained the maximum available fission product inventory and that the events leading to the release of radiological material to the environment occur after the weather conditions required for testing can no longer be assured. The analysis used significantly deteriorated weather conditions to evaluate this scenario and produced the following results which are well below the ANSI/ANS guidance of 500 mrem:

- NTS: 23.5 mrem
- INEL: 30.0 mrem

Figure 4.12-1 provides a graphical summary of these results, along with applicable regulatory criteria and exposure guidance. This figure also portrays the natural dose at NTS and INEL for comparison. Appendix H provides additional information concerning ionizing radiation, its biological effects, and exposure evaluation; and is provided to aid the reader with the terms used in this analysis.

Section 4.12.3 presents non-radiological hazards associated with construction of the test facility and operation of the PBR validation test program are evaluated. Areas considered include transportation, storage and handling of cryogenic (low-temperature) fluids, facility construction, and



Magnitude of Dose Impacts to Maximum Exposed Individual

Figure 4.12-1

management of hazardous materials. Evaluations are presented which include hazards associated with planned operations, as well as possible accident occurrences. In all cases, potential hazards are found to be controllable, and do not present adverse impacts to individuals, the community, or the test sites.

Section 4.12.4 provides a discussion of each site's emergency response procedures and accident recovery plans. The procedures are currently in place at each site, and are intended for use in the event of an accident.

4.12.1 Safety Analysis Review Process

The Department of Energy (DOE), in accordance with its statutory responsibility under the Atomic Energy Act of 1954 (as amended), would require Safety Analysis Reports (SARs) to be submitted and approved prior to the construction and initial nuclear operation of the PBR validation test facility. This established SAR process, which is applied to all DOE reactors, would document the adequacy of the safety analysis for the PBR validation test facility to ensure that this facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations. An overview is provided of the SAR process promulgated by two DOE Orders: DOE Order 5480.6, which requires that a safety program be established for each DOE nuclear reactor to ensure proper consideration of safety issues in all phases of reactor design, construction, operation, and decommissioning; and DOE Order 5480.23, which establishes uniform requirements for the preparation and review of SARs which describe the safety program and analyses. Major features of an SAR are described, as are the several steps through which every SAR must proceed prior to construction and operation of the facility.

An SAR would include the documentation of a series of analyses accomplished to indicate the impact of the facility to the environment under normal operating conditions and by credible departures from those normal operating conditions. These "off-normal" situations may be the result of internal events, such as component failures or operator errors, or external events, such as earthquakes or loss of off-site power supplies. The SAR would demonstrate that all such eventualities have been considered and are at least bounded by the analyses. The analyses would address both the probability of these events occurring and the potential resulting consequences. If either the probability or the severity of a given scenario is of sufficient concern, the system may be required to include safety measures or features to mitigate that specific risk. The SAR would then include detailed assessments of those safety features.

Another major component of an SAR would be the description of those accidents which, based on their probabilities, potential consequences, or the fact that they constitute a bounding case for other accident sequences,

have been selected for analysis. These accident analyses would identify some of the design requirements which must be met by the proposed system and are usually referred to as design basis accidents. Safety analyses also often consider accidents, and system responses to those accidents, more severe than design basis accidents; these analyses are reported as supporting information to the approval process.

The SAR process would also include all identified safety concerns in the design development process to ensure their proper consideration. The process would also provide clear safety design requirements and specifications, limits on operating conditions, and Technical Safety Requirements.

An SAR must pass through several levels of approval, including at each level some measure of independence between those reviewing, commenting upon, and approving the work and those who prepared the material. The following description is keyed toward the SAR process for the PBR propulsion technology development and validation throughout the life of the test program.

First, the system design team develops a design of the hardware and operations systems which meets the SNTP program performance requirements. Concurrent with this activity, the safety team identifies potential hazards associated with the system, and all applicable laws, regulations, and codes, and determines the design requirements necessary to ensure that safety has been considered adequately and is reflected in the design. Second, the design is reviewed internally within the SNTP program organization. Safety is given top priority in all program activities. Third, the SAR would be reviewed by the expected DOE reactor operating contractor organization. Typically, this is a two-level review. The first level is primarily a technical review, and is comprised of individuals not directly involved in the development of the system under review but having the technical expertise to judge the adequacy of the design to meet its requirements, especially those addressing the safety of the system and its operation. The second level is at a management level, again, representing appropriate technical expertise and expressly including management representatives from safety and health physics organizations. This oversight would continue throughout the life of the test project.

Fourth, the SAR is submitted to DOE. Review at DOE begins at the Field Office level and independent safety review experts are typically assembled into a review team. The SAR would then be reviewed and approved by DOE Headquarters. DOE Headquarters' approval is documented in a Safety Evaluation Report (SER) which would allow either construction if approving the PSAR, or operation if approving the FSAR. After initiation of construction or operation the DOE reactor operating contractor would be

held responsible by DOE for adhering to the assumptions and commitments set forth in the SAR.

After the SAR is approved, DOE Orders require that it is updated and "reapproved" periodically. Additionally, modifications to the test program which are promulgated between reapprovals of the SAR would be evaluated for impact on safety.

Throughout the facility design and approval process, end-of-life requirements are considered to ensure that (1) appropriate decontamination and decommissioning are feasible and (2) design features to enhance the effectiveness of decontamination and decommissioning procedures are included. Finally, as the program approaches completion, detailed plans are developed and subjected to a review process similar to that described above.

4.12.2 Radiological Hazards

4.12.2.1 Radiological Release Assessment Methodology. Assessment of the radiological releases and subsequent radiation exposure from normal operations and plausible accident scenarios was performed for both PBR test reactor operations and transportation of radiological materials. Assessments were performed using computer modeling techniques, based on information describing normal operations and credible accident scenarios which result in the maximum radiological impacts. Included in accident scenario development was consideration of multiple concurrent hydrogen explosions, which, however, were found to induce no added impacts for any of the identified analysis scenarios. A complete discussion of the development of this methodology is provided in Appendix E, Section 1.0.

Model Selection

Several computer modeling codes were evaluated for analysis of radiological impacts due to reactor operations and accidents; among these were AIRDOS-PC, CAP-88, RSAC-4, and MACCS (MELCOR Accident Consequence Code System). Either AIRDOS-PC or CAP-88 will be used to demonstrate regulatory compliance with 40 CFR Part 61, Subpart H (NESHAP). However, MACCS was selected for the safety analysis because of its ability to evaluate a large number of isotopes and to evaluate short-term releases associated with PBR propulsion technology assessment. Of the codes evaluated, MACCS was also determined to yield the most conservative results.

Evaluation of radiation exposures as a result of the transportation of radioactive materials (including accidents) was evaluated using the RADTRAN-4 code. This code was developed by Sandia National

Laboratories (SNL) specifically to analyze the impacts of radioactive material transport, and represents the best available model of its kind.

Selection of Meteorological Conditions

PBR propulsion technology test reactor operations will occur over short periods of time (less than 1,000 seconds), and total test operations will last on the order of several hours from start to finish. This allows pre-test evaluation of prevailing meteorological conditions to ensure that potential impacts will be within acceptable program criteria. Prior to test operations, forecasting of meteorological conditions will be performed which will encompass a period of approximately ten to twelve hours with a high degree of certainty. Real-time evaluation of radiological impacts that could result from an accident under these meteorological conditions may be used to determine whether or not to proceed with the test.

Since the acceptability of weather conditions is based upon real-time assessments of potential impacts in the event of an accident, individual weather parameters may vary over considerable ranges. However, to allow quantitative estimates of the potential impacts for this EIS, a set of "model operating conditions" has been selected which both meet acceptance criteria and occur with high relative frequency at each test site. These are presented in Table 4.12-1 and are used for analysis of all normal operations and test-time accidents. Since the reliability for duration of test weather conditions may be as short as 10 hours, it is conceivable that beyond that time weather conditions could change considerably. Such a change could create conditions which would not have been acceptable at the start of a test due to potential severity of accident impacts, but which could influence accident events occurring several hours after test completion. Table 4.12-2 presents such weather criteria which, while not meeting test-start acceptance criteria, were selected as capable of producing maximal impacts. These conditions are used in the analysis of accidents occurring more than 10 hours after test-start.

Table 4.12-1. Model Weather Conditions

	NTS	INEL
Air Stability Category	Neutral	Neutral
Wind Speed (meters per second)	5.5	5.5
Plume Direction	NNE ^(a)	NNE ^(a)
Inversion Base Height (meters)	2,000	1,500

(a) Generally in the northerly direction.

Table 4.12-2. Bounding Accident-Case Weather Conditions

	NTS	INEL
Air Stability Category	Moderately Stable	Moderately Stable
Plume Speed (meters per second)	1.0	1.0
Wind Direction	Highest Population	Highest Population
Inversion Base Height (meters)	300	300

At both NTS and INEL, meteorological conditions for each set of parameters were selected based upon data provided by the nearest NOAA-operated monitoring station to the proposed test sites (SMTS and CTF).

Radiological Releases

The "source term" represents the amount of radioactive material released to the environment. It is the product of the total core radiological inventory multiplied by applicable release fractions and is the basis for impact determinations developed with MACCS. The source term can vary in magnitude based upon both the type and condition of the reactor involved (which affects the total amount of radioactive material available for release - referred to as the total core inventory) and the fractional amounts of each nuclide which escape to the environment.

Fission products, which are created during the fissioning of uranium fuel in the reactor core, account for more than 99 percent of the total core inventory. Thus the total fission product inventory present in a core during and after test operations accurately represents the total core inventory of radioactive material. The total value of the core fission product inventory is based upon both the length of time at which a core has been operated and the power level of the operations. In this evaluation, determination of the core fission product inventory is based upon the following maximum-case test operations:

- **PIPET:**
A five operation test series with each test consisting of an operational power level of 550 megawatts, operating for a period of 500 seconds. After each test run the value of the total core inventory increases due to production of additional fission products
- **GTA:**
One operation of 2,000 megawatts for 1,000 seconds.

Once fission product inventories have been calculated, it is necessary to determine the amount of each isotope which would be released from the

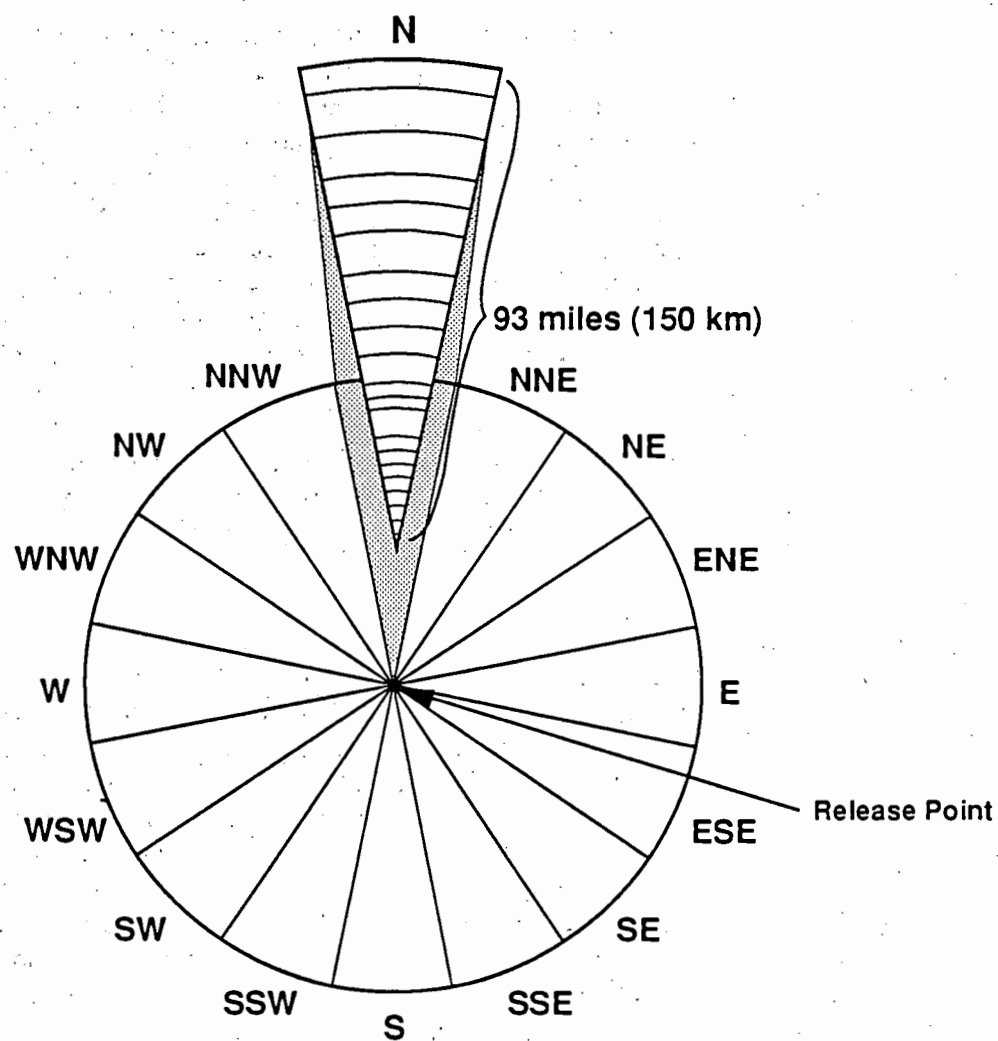
core. In the event of accidents, or for tests that evaluate design limits, it is conservatively assumed that the entire fission product inventory is released to the ETS.

For other types of operations, calculations have been performed to estimate the quantities of isotopes released. Of the total number of isotopes present in the core, the release fractions of 55 radionuclides (representing more than 75 percent of the radiological impact potential) have been calculated specifically, and are presented in Table E-5 of Appendix E. Conservative assumptions have been made concerning the release fractions of the remaining inventory isotopes through classification of nuclides into four chemical groups, for each of which percentage release values have been developed. These values are presented in Table E-6 of Appendix E. Fission products released from the core will enter the ETS, which has design goal retention efficiencies of 99.5 percent for volatiles, halogens, and nobles, and 99.9 percent for particulates. The final source term for each analysis is calculated by applying these ETS retention efficiencies to the fraction of the core inventory which is released, and determining the resulting quantities of radioactive material which escape to the environment.

Population Data

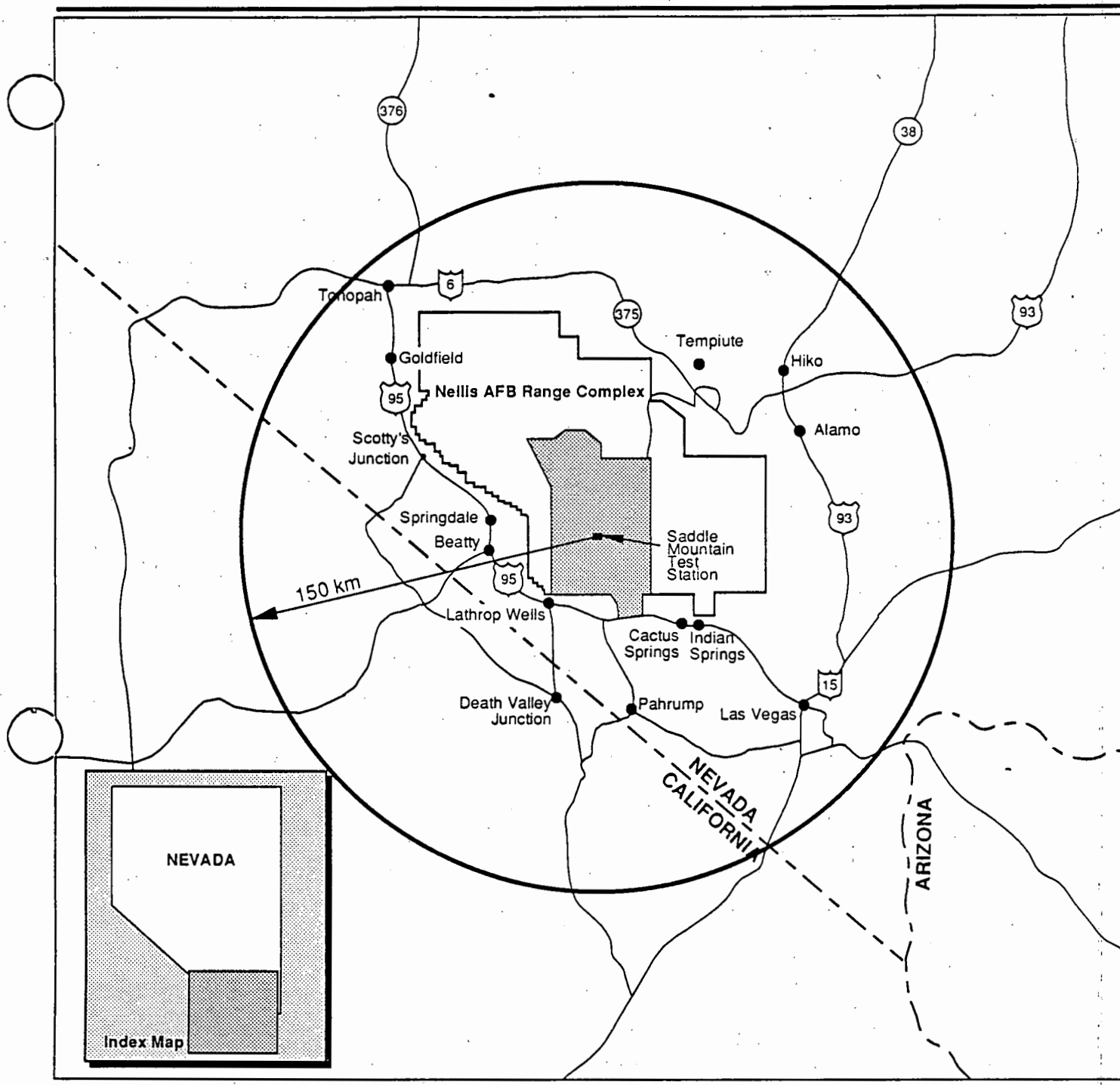
Normally, consequence analyses for total population exposures are performed for areas within 80 kilometers from the potential release point. However, for this assessment, the potential radiological impacts of PBR validation testing at distances up to 150 kilometers have been included in estimating total population exposures. This allows inclusion of major population centers near each proposed test location. Beyond this distance, the total population exposure will drop off rapidly, contributing little additional dose. (Although the contribution to total population dose from these outlying areas is very small, the calculations sometimes show the Maximum Exposed Individual [MEI] to be beyond 150 kilometers. Therefore, peak MEI doses at greater distances are included in the results reported here).

For input into MACCS, population data are arranged into a circular (polar) grid divided into 16 directional sectors and 26 radial distances measured outward from the release point to 93 miles (150 kilometers) (Figure 4.12-2). The size of each radial segment increases with increasing distance from the release point. Population data are taken from the most recent census data available for each site, and are used to determine the total population dose resulting from each release analyzed. The areas considered around NTS and INEL are illustrated in Figures 4.12-3 and 4.12-4, respectively.



MACCS Polar Grid

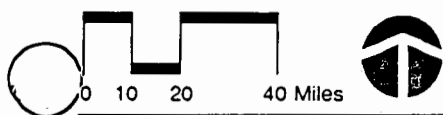
Figure 4.12-2

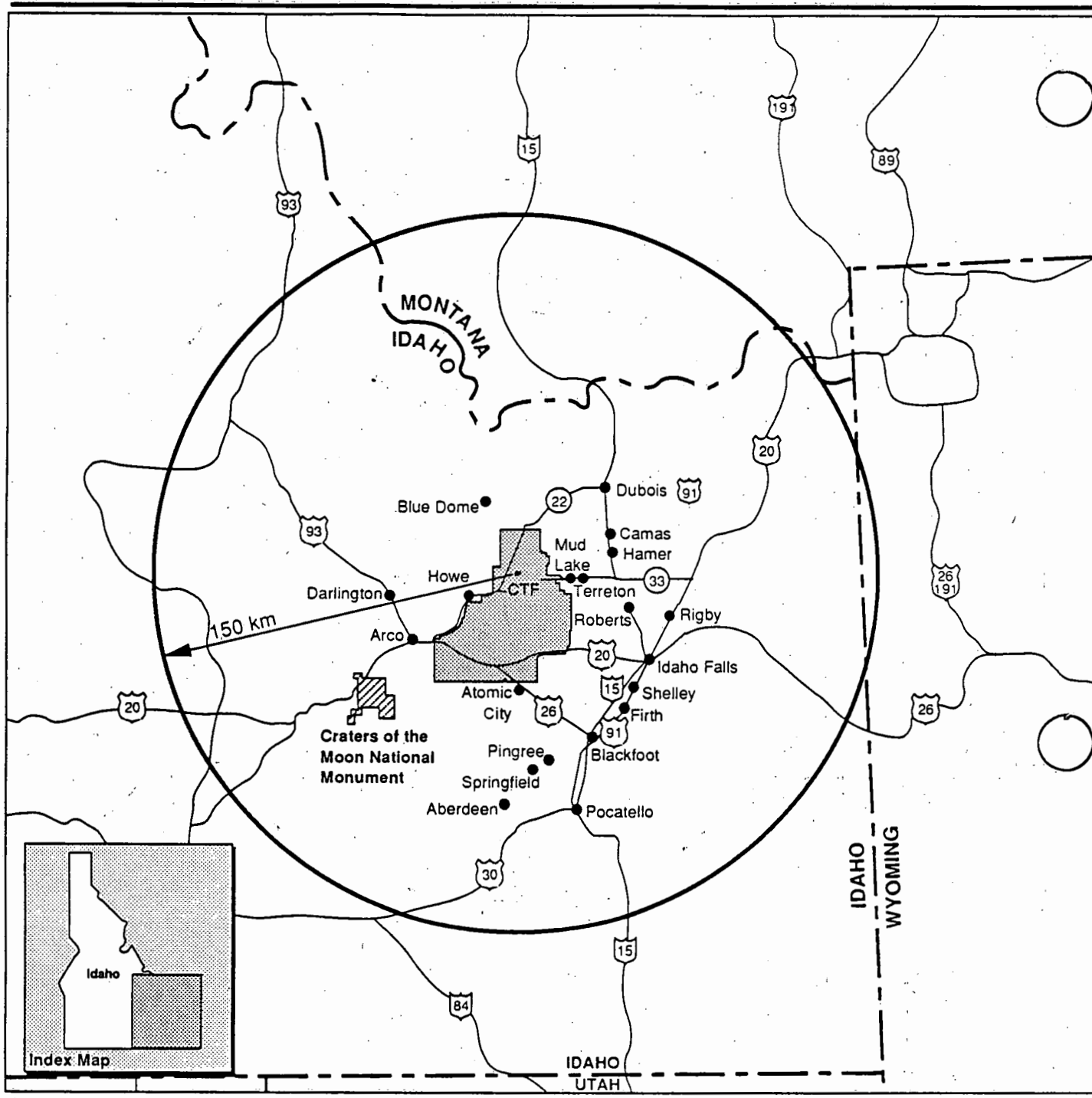


Nevada Test Site

Radiological
Analysis Region

Figure 4.12-3

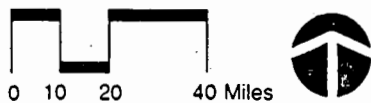




Idaho National
Engineering
Laboratory

Radiological
Analysis Region

Figure 4.12-4



Potential Impacts

Results of the MACCS analysis are presented as maximum potential impacts to any individual (the MEI), expressed in units of mrem. The analysis also estimates the total dose received by the entire exposed population, which is the sum of all individual exposures and is expressed in units of person-mrem.

The values for the MEI represent the cumulative dose from both internal and external exposures (excluding ingestion) on a whole-body basis. The summation of all operations in a year yields the MEI, which can be evaluated against both the NESHAP standard of 10 mrem and the PBR validation technology program goal of less than 2 mrem total dose to the MEI.

The total population dose can be used to estimate the numbers of long-term cancers and genetic disorders which may develop in the exposed population. This is accomplished by applying average cancer and genetic disorder exposure risk criteria from the 1991 report issued by the Committee on the Biological Effects of Ionizing Radiation (referred to as BEIR V), which are 7.9×10^{-7} latent cancers per person mrem and 2.6×10^{-7} genetic effects per person mrem. This analysis provides estimated numbers of induced cancers and genetic disorders expected based upon the projected radiological impacts that can be compared with the naturally expected rates of occurrence of these effects in the exposed populations (due to a variety of medical phenomenon). In the United States, it is estimated each year one person in 220 will develop cancer, and that each year one person in 4,545 will develop a genetic disorder (Mayernick, 1992). Accordingly, at NTS, there is a potentially exposed population of 1,072,718, which would be expected to experience approximately 243,800 cancers and 11,800 genetic disorders over a fifty-year period. At INEL, the potentially exposed population of 272,082 would be expected to experience approximately 61,800 cancers and 3,000 genetic disorders within a 50-year period.

4.12.2.2 Public Exposure during Normal Operations

Design Criteria

Title 40 CFR Part 61, Subpart H (NESHAP) specifies an annual exposure limit of no more than 10 mrem per year to any individual. However, the SNTP Program has a design goal of 20 percent of this standard (2 mrem).

Operational Scenarios

Normal, planned operations will entail the release of small quantities of radioactive materials (primarily noble gases, halogens, volatile elements, and some particulates) to the atmosphere. These represent materials released from core fuel particles which escape the ETS, as well as post test release

of noble gases and other volatile isotopes (held in the ETS for 1 day). Together the releases constitute the source term used in the MACCS analysis.

Three different categories of operational tests have been identified, based upon the required performance of the core, and have been designated Normal I, Normal II, and Normal III. Each of these categories has been evaluated for both PIPET and Ground Test Article (GTA) cores. Some combination of these operations will be conducted annually (described below), and the sum of the releases associated with each will result in the total year's radiological impact.

Normal I. Normal I experiments include initial startup, zero-power, and low-power physics tests. Testing under these conditions would not release radiological materials to the environment since test conditions would be significantly below full-power operating conditions. For this reason, Normal I experiments are not discussed or analyzed further.

Normal II. Normal II experiments are standard tests that would operate within the fuel design envelope, up to the core's rated full power (550 MW for PIPET and 2,000 MW for GTA). These experiments would release small amounts of the core inventory during each test. The amount of fission products released as a result of a Normal II operation would be the same as discussed under Radiological Releases. PBR propulsion technology Normal II experiments would be performed using both GTA and PIPET cores.

Normal III. Normal III experiments, which would be performed using PIPET cores only, involve operations to determine fuel design margins, with the intent of quantifying actual design limits. These experiments could include over-power, reduced coolant flow, and extended duration testing. These tests may involve full or partial fuel element failure where some fraction of the fuel in one or more fuel elements is released into the ETS. Current assessments of these experiments envision reduced run times (minimizing the inventory) with only partial failure of some of the fuel elements (minimizing the release). However, for purposes of performing conservative impact analyses, it is assumed that 100 percent of the core fission product inventory is released following a maximum case test. It is important to realize that the intent of these tests is to define the design margin, not to purposely fail the core.

Identification of Bounding Case Scenarios

The maximum case yearly operational impact is presented in Table 4.12-3. Each test is assumed to be a full-power, maximum duration test as described under Radiological Releases. Impacts from individual tests are presented in Appendix E, Section 2.0. The PIPET Normal III test is considered as the fifth run of the reactor core operations test series. The

reported impact is the result of the sum of the releases from each of these operations.

Table 4.12-3. Maximum Year Test Operations

Operation Type	Number
PIPET Normal II	9
PIPET Normal III	1
GTA Normal II	2
Total	12

Impacts from the entire PBR propulsion technology development and validation program are based upon the cumulative effects of a 10-year long test program. This would consist of one five-operation PIPET test series (all Normal II) and one GTA maximum run (Normal II) operation each year, with a total of four PIPET Normal III operations during the 10-year period replacing four of the PIPET Normal II tests (for conservatism Normal III operations are assumed to occur as the fifth operation of the test series).

Impact Assessment

Impacts are presented at the facility boundary (the nearest NTS/INEL public access boundary in the selected wind direction), the location of maximum offsite impact (MEI), and to the total exposed population. The radiological doses presented in these analyses are expressed as the sum of the external doses received from cloudshine and groundshine, and the organ-weighted internal doses received from inhalation during plume passage and later resuspension inhalation, integrated over a 50-year period. Population doses also include the dose from ingestion of contaminated food and water. Virtually all the committed dose would be received in the first year following the radiological release; therefore, whole-body MEI doses can reasonably be compared with a single year exposure from natural radiation. Additional information concerning radiation effects and exposure measurement is presented in Appendix H.

Maximum Annual Operations. Tables 4.12-4 and 4.12-5 show the MEI and population doses, respectively, for the maximum yearly total release. The dose at the NTS boundary following the maximum yearly release from SMTS would be approximately 0.16 mrem. The MEI would occur at approximately 195 kilometers with a magnitude of 0.60 mrem. The dose at the INEL boundary following the maximum yearly release at CTF would be approximately 0.10 mrem. The MEI at INEL would occur at approximately 125 kilometers with a magnitude of 1.35 mrem. These values are well

Table 4.12-4. Maximum Yearly Release 50-Year Center-Line MEI

Site	Site Boundary		Peak Dose		1-year Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	0.16	39	0.60	195	422
INEL	0.10	15	1.35	125	441

below both the NESHAP standard of 10 mrem and the SNTP program goal of 2 mrem.

Population doses for the maximum yearly release results in the projection of approximately 0.02 additional cancer fatalities and 0.01 additional genetic disorders at NTS, and the projection of approximately 0.11 additional cancer fatalities and 0.045 additional genetic disorders at INEL.

PBR Propulsion Technology Development and Validation Impacts. During the 10-year lifetime of the PBR propulsion technology development and validation, impacts from each year would accumulate and collectively produce the total program-related doses. During most years of the test program, fewer test operations will be conducted than during the maximum year, therefore an average year in the ten year sequence is considered to consist of five PIPET Normal II Operations, and one GTA Normal II operation. During the 10-year test period a total of four PIPET Normal III operations will occur replacing four of the PIPET Normal II tests.

Tables 4.12-6 and 4.12-7 present the cumulative impacts from the proposed PBR propulsion technology assessment program. Both site boundary and peak doses are listed for comparison.

Table 4.12-6. Total SNTP Program Cumulative Center-Line MEI

Site	Site Boundary		Peak Dose		10-Year Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	0.64	39	2.5	190	4220
INEL	0.06	15	5.6	125	4410

The dose at the NTS boundary for releases from SMTS would be approximately 0.64 mrem. The MEI would occur at approximately 190 kilometers with a magnitude of 2.5 mrem.

Table 4.12-5. Maximum Yearly Release 50-Year Population Dose

Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose (Person-mrem)	Total Pop. Dose (Person-mrem)	Latent Cancer Fatalities		Genetic Disorders	
							Additional Cases	Increase Above Expected (%)	Additional Cases	Increase Above Expected (%)
NTS	NNE	917	114	1,072,718	7,457	27,571	0.022	9.0×10^{-6}	0.007	5.9×10^{-6}
INEL	N	5,846	1,983	272,082	31,468	133,451	0.105	0.00017	0.035	0.0012

Table 4.12-7. Total SNTP Program Release 50-Year Population Dose

Core/ Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose (Person-mrem)	Total Pop. Dose (Person-mrem)	Latent Cancer Fatalities		Genetic Disorders	
							Additional Cases	Increase Above Expected (%)	Additional Cases	Increase Above Expected (%)
NTS	NNE	917	487	1,072,718	112,956	113,442	0.09	3.7×10^{-5}	0.03	0.00025
INEL	N	5,846	8,104	272,082	542,528	550,634	0.44	0.00071	0.14	0.0047

The dose at the INEL boundary for releases at CTF would be approximately 0.06 mrem. The MEI at INEL would occur at approximately 125 kilometers with a magnitude of 5.6 mrem.

Population doses for the lifetime of PBR propulsion technology assessment results in the projection of approximately 0.09 additional cancer fatalities and 0.03 additional genetic disorders at NTS, and the projection of approximately 0.44 additional cancer fatalities and 0.14 additional genetic disorders at INEL. These projected impacts are very small in comparison to naturally occurring cancers and genetic disorders.

Transportation of Radiological Materials

Shipment of fissile radioactive materials is regulated by the requirements of 49 CFR Part 173, Subpart I. Transportation requirements for shipment of non-fissile radioactive material (also in 49 CFR Part 173, Subpart I) limit external radiation dose rates, radioactive material contamination levels, temperature, pressure and containment.

The radiological impacts associated with routine (non-accident) transportation of uranium bearing fuels, both unirradiated and irradiated, TRU waste, and low-level waste have been calculated using the RADTRAN 4 computer system (Neuhauser and Kanipe, 1991). Data used in the analysis include the material properties characteristic of shipping containers and contents, transport vehicles, numbers of shipments and distances traveled, and population distribution for actual routes to and from the facilities involved. Appendix E, Section 3.0 provides a detailed discussion of the transportation modeling effort.

The radiological impacts result from limited direct external radiation exposure to people sharing the roads with transport vehicles, and those living near the roads or near rest stops. The population dose increase to this population from incident-free PBR material shipments to NTS and INEL is conservatively calculated to be 113,000 person-mrem, and 132,000 person-mrem respectively. This represents the total dosage received by all persons exposed to the shipment during transit and consists primarily of minute doses to a large number of motorists exposed for short time periods. The potential increase in the incidence of radiation-induced health effects due to these total population exposures would be approximately 0.09 additional cancer fatalities and 0.03 additional genetic disorders from transportation to NTS, and approximately 0.1 additional cancer fatalities and 0.03 additional genetic disorders from transportation to INEL.

4.12.2.3 Public Exposure as a Result of Potential Accidents. Accidents involving the GTA and PIPET cores could result in release of radiological materials with consequences exceeding those described in the previous section. This may include release of considerably higher fractions of core

inventory materials from the fuel particles, and/or release of materials from the ETS prematurely. A series of accident scenarios have been identified, and have been evaluated to determine the appropriate bounding case scenario(s). These have been designated Consequence I, Consequence II "Early," Consequence II "Late," and Consequence III. From these scenarios, an appropriate bounding case accident was selected for MACCS analysis which represents the maximum credible accident impact. In the development of these scenarios consideration was given to multiple concurrent internal and external explosions of hydrogen; however no increase in potential consequences of any scenario was found.

Design Criteria

For the ground test facility, the American National Standards Institute (ANSI)/American Nuclear Society (ANS) Report 15.7 has been identified as providing the most conservative siting guidance. This standard is jointly established by the ANSI and the ANS for application to test reactors, and represents a conservative limit which should be allowed for public exposure as a result of an accident. The maximum allowable doses to an off-site individual from a reactor accident specified in ANSI/ANS Report 15.7 are 500 mrem whole body and 1,500 mrem to any organ, accumulated from a 2-hour exposure for rural populations or a 24-hour exposure for urban populations.

ANSI/ANS Report 15.7 defines radiological dose limits in terms of zones around the test facility. The innermost zone, the operations area, is that area in the immediate vicinity of the test facility set off by a physical barrier such as a fence over which the test facility administrator has access and activity control. The operations area is surrounded by a site in which there may be people only generally aware of test facility activities and emergency responses. Outside the site is a rural zone, generally an area that may include members of the general public, but limited to populations which could reasonably be evacuated or protected within 2 hours. The urban zone (i.e., the area outside the rural zone) includes populations too large (greater than 25,000) to assume such evacuation or protection; instead an exposure time of 24 hours is assumed.

Selection of Bounding Case Scenarios

Consequence I. A Consequence I accident is considered the maximum possible hypothetical accident. The accident assumes the total release of all radioactive material of a maximum inventory GTA core immediately following operation. The inventory is assumed to be released in a completely aerosolized fashion to maximize the radiological consequence off site. The release is assumed to bypass completely the ETS and any secondary confinement. No account for agglomeration, condensation, or scavenging processes is taken, which ensures that the maximum inventory

is dispersed outside of the test site boundary. Each of these assumptions represents an overly-conservative bound which cannot be realized physically.

Consequence II. A Consequence II accident is considered the maximum credible postulated accident scenario. A Consequence II accident can result if two critical ETS components fail following the end of a maximum operational cycle, when the maximum inventory is present in that component. The critical components are assumed to be the cryogenic adsorber beds (a series of multiple parallel stages), and the ETS emergency confinement system (emergency closure valves). They are assumed to have the potential to fail any time during or following an operation. For conservatism, 100 percent of the core is assumed to be released into the ETS in this case (the result of a PIPET Normal III operation or a GTA failure). For this case all of the noble gas inventory is released into the atmosphere. Particulates and other non-gaseous materials are mainly trapped in the ETS particulate and charcoal filters, and thus not released. This accident is considered for PIPET only. It would require the simultaneous failure of three independent systems for a GTA reactor to experience this scenario (reactor core and ETS systems), which is considered unrealistic.

Two different failure times are considered. The first occurs immediately following the end of a PIPET Normal III operation. Model weather conditions are assumed, since this release would occur within the 10-hour forecast window. This accident is termed the Consequence II "Early" scenario.

Should the adsorber beds fail more than 10 hours after the test, model weather conditions can no longer be assumed. Instead, credible weather conditions which produce the maximal impact are assumed to prevail (moderately stable air, 1.0 meter per second wind speed, and a 300 meter inversion layer base). Additionally, the wind is assumed to be blowing directly toward the nearest maximum population center (Las Vegas at NTS and Idaho Falls at INEL). This accident is termed the Consequence II "Late" scenario in the remainder of this section.

Consequence III. During initial installation of a GTA or PIPET core, some zero or low-power testing (Normal I operations) would be conducted. Although highly unlikely, an accidental reactor control rod withdrawal could occur before the reactor containment and confinement system are in place. In this event, the reactor would experience a brief, but intense, power excursion which could result in fuel vaporization and subsequent release directly into the atmosphere. The resulting inventory would contain fission products from approximately 10^{18} fission events (equivalent to 110 MW for 0.5 seconds of GTA operation) (Sherman, 1991), and would be released at ground level. Although the intent would be to perform the zero-power testing in model weather conditions, weather conditions producing the maximal impact are assumed for conservatism (moderate stability, 1.0 meter

per second wind speed, and a 300 meter inversion height). Additionally, the wind is assumed to be blowing directly toward the nearest maximum population center (Las Vegas at NTS and Idaho Falls at INEL).

Preliminary analysis performed using these accident scenarios has shown the Consequence II "Late" accident with a PIPET core to be the appropriate bounding case scenario. Although greater impacts can be calculated using a Consequence 1 accident (presented in Appendix E, Section 2.0), no credible design-based situation is conceivable which could result in its occurrence, thus it will not be considered in this analysis. The potential for occurrence of even a Consequence II type accident with a PIPET core is remote, since it would depend upon the simultaneous failure of two independent reactor systems; failure of the complete ETS cryogenic adsorber system, and failure of the confinement or isolation system which would otherwise prevent uncontrolled release of radioactive material during an accident. The probability of such an occurrence, termed a "two-point" failure, is remote; while the failure of either system is low, the simultaneous failure of both is almost inconceivable.

Bounding Case Accident Impacts

Tables 4.12-8 and 4.12-9 list the MEI and population dose, respectively, for the Consequence II "Late" accident. The site boundaries for this accident are reported closer to the release point (23 kilometers at NTS, and 3 kilometers at INEL) than was used in the Normal-case operations analyses as a result of the wind direction changes. At INEL, determination of site boundary is set by a public highway which travels within 3 kilometers of the CTF, since non-site personnel may have access to this location after test operations.

Table 4.12-8. PIPET, Consequence II "Late" Accident Plume Center-Line MEI

Site	Site Boundary		Peak Dose		1-Year Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	23.5	23	23.5	23	422
INEL	24.0	3	30.0	10	441

The dose at the NTS boundary for this accident occurring at SMTS is approximately 23.5 mrem, which also corresponds to the MEI. At the INEL site boundary of 3 kilometers, the impact from occurrence of this accident is approximately 24 mrem, while the INEL MEI impact of 30 mrem occurs at a distance of 10 kilometers. Although these values do not take into account

Table 4.12-9. PIPET, Consequence II "Late" Accident 50-Year Population Dose

Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose	Total Pop. Dose (Person-mrem)	Latent Cancer Fatalities		Genetic Disorders	
							Additional Cases	Increase Above Expected (%)	Additional Cases	Increase Above Expected (%)
NTS	SE	974,109	401,000	1,072,718	64,000	465,000	0.37	0.00015	0.12	0.0010
INEL	SE	65,781	350,000	272,082	1,360,000	1,710,000	1.4	0.0023	0.44	0.015

the effects of evacuating, they are well below the ANSI/ANS Report 15.7 guideline of 500 mrem (0.5 rem).

Population doses as a result of a Consequence II "Late" accident are evaluated in the south east (SE) wind sector for NTS (i.e., Las Vegas), and the SE sector at CTF (i.e., Idaho Falls). The projected latent effects which may be caused by the Consequence II "Late" accident may be approximately 0.37 additional cancer fatalities and 0.12 additional genetic disorders at NTS, and approximately 1.4 additional cancer fatalities and 0.44 additional genetic disorders at INEL. These values represent the maximum accident-case impact for PBR propulsion technology assessments.

4.12.2.4 On-Site Area Contamination

No ground contamination is expected as a result of normal operations. The maximum credible accident that resulted in the greatest consequence to the public and on-site workers is primarily an airborne gaseous release that would not result in significant ground contamination. Ground contamination from other accidents are anticipated to be localized within the facility boundary (dispersing over 100 acres or less). Estimates of bounding case evaluations of on-site ground contamination are presented in Appendix E. No significant off-site ground contamination is expected and material deposited off site would be far too diffuse to require cleanup. The impact of any radioactive material deposited off site is included in the consequence evaluations that estimate individual and population doses.

Transportation Accident Impacts

The impacts of potential accidents involving the transport of unirradiated and irradiated fuel including transport of radioactive and mixed waste were analyzed using the RADTRAN 4 code (Neuhauser and Kanipe, 1991). The analysis required a definition of the properties of the material to be transported, a description of accidents that might occur, and representative transportation routes. It was assumed that materials shipments include the following: shipment of fuel material to Lynchburg, Virginia, from Oak Ridge, Tennessee; shipment of select unirradiated fuel specimens from Lynchburg, Virginia, to Albuquerque, New Mexico; and shipments of unirradiated fuel elements and assemblies, up to and including full GTA from Lynchburg, Virginia, to NTS or INEL. The irradiated fuel elements are assumed to be shipped back to Lynchburg, Virginia, for analysis. Details of the transportation analysis are presented in Appendix E, Section 3.0.

The transportation analysis uses both route-specific and national average transportation data. The route-specific data include total distance, adjacent population, and fraction of the route on various types of roads (e.g., rural, urban, or suburban). The road-type fractions are then combined with national average truck accident data for each road type, and data specific

for DOE transport vehicles (Safe Secure Transport [SST]). The national average data used in the analysis yield accurate risk estimates for the cross-country routes to which they were applied. Data included in Appendix E, Section 3.0 show that the national average combination-truck accident rate on interstate highways is about 3.1×10^{-7} accident per kilometer. Limited variability in accident rates supports the use of national average data. For on-site shipments, the analysis does account for relevant site-specific factors such as low population density.

Weather-related road closures in the region are not expected to affect the risk estimates. Effects due to weather would be kept to a minimum by considering actual and forecast road conditions and by not dispatching trucks either in bad weather or under poor forecast conditions. Restricting truck transport to good weather conditions would reduce the overall truck accident rate by only about 10 percent (NRC, 1977). Since accidents associated with travel in poor weather conditions are included in the DOT accident-rate data that were used in the risk analysis, the risk estimate is slightly conservative with respect to this parameter. The stop time is based on actual operational requirements for SST shipments. A decreased stop time does result in a decrease in incident-free risk but has no effect on accident risk calculations.

The consequences of a severe accident involving the transport of enriched uranium are presented in the NRC Final EIS on Radioactive Material Transport (NRC, 1977) in terms of both the number of potential latent cancer fatalities (LCFs) and the economic consequences (e.g., cleanup and agricultural products). In evaluating both the consequences and risks of radioactive material transport, including severe accidents, the NRC concluded that "the risks attendant to accidents involving radioactive material shipments are sufficiently small to allow continued shipments by all modes."

The estimated radiological risks from transportation accidents associated with program shipments based upon RADTRAN 4 analysis would be approximately 0.94 person-mrem for shipments to NTS, and 1.03 person-mrem for shipments to INEL (reference Appendix E, Table E-27). These exposures may result in the projection of approximately 7.4×10^{-7} additional cancer fatalities and approximately 2.5×10^{-7} additional genetic disorders from NTS transportation, and up to 8.1×10^{-7} additional cancer fatalities and up to 2.7×10^{-7} additional genetic disorders from INEL shipments. For non-radiological transportation risks, RADTRAN 4 analysis projects up to 0.21 fatalities due to shipments to NTS, and 0.23 fatalities due to shipments to INEL.

4.12.2.5 Worker Exposure

Regulatory and Design Criteria

On-site workers may potentially be exposed to radiation due to operation of the PIPET and GTA reactors, as well as the subsequent decay radiation from core inventories. DOE Orders specify a limit of 5,000 mrem per year for radiation workers. The recently released DOE Radiological Control Manual suggests a design goal for limiting annual worker operational exposures to 500 mrem. In order to provide an adequate margin for dose limits such that special operations (which may entail planned additional exposures) can be performed, the yearly averaged facility occupational dose rate must be maintained at a level significantly below that which would result in the general facility worker receiving a maximum annual dose allowance. To provide this margin, the design objective is to limit normal operational exposures to 20 percent of 500 mrem, i.e., 100 mrem. Assuming that a worker is on site for 8 hours per day for 236 days per year, this is equivalent to 0.053 mrem/hr.

Normal Operations

During maintenance activities, workers will be required to function in the vicinity of reactor cores, which will present a considerable dose potential. In order to reduce the dose rate to desired levels, the use of shielding around the reactor core(s) will be required. Dose rate calculations were performed using MICROSIELD and MICROSKYSHINE for both direct radiation and skyshine from a radiation source. The direct radiation calculations provide a basis for establishing lateral shield requirements, while the skyshine calculations provide a basis for overhead shielding requirements. A point radiation source was assumed for the bulk of calculations, although periodic checks were made assuming more complex distributed source terms.

The most pessimistic assumptions are that all the facility isotope inventory resides in a single point and the 1-day dose rate level is to remain within the dose rate limits for a radiation worker (0.053 mrem/hr). Analyses to date have shown that approximately 2 meters of concrete lateral shield and 1 meter of overhead shielding is required to permit a worker to be as close as 10 meters to the source on a regular basis.

The most optimistic assumptions are that only 2.5 percent of the total facility fission product inventory resides in the point source and that the dose rate level after 8 days is to remain within the dose rate limits. Under these conditions only 1.4 meters of concrete are needed for lateral shielding and 0.7 meters for overhead shielding.

Assuming adequate lateral shielding, the approach to the source by a radiation worker would thus be limited primarily by skyshine. Note that if no overhead shielding were provided for a laterally shielded radiation source, a radiation worker could not routinely be within 800 meters of the source for the pessimistic case. Even for the optimistic conditions, routine worker approach would be limited to approximately 500 meters.

For the pessimistic case, a cover thickness of a little over 2 meters of concrete would allow the worker to routinely work above the source. A cover thickness of 1.2 meters of concrete would allow the worker to approach the edge of the source location routinely (provided adequate lateral shielding is in place).

While the specific determination of the doses expected for on-station and on-site workers must be deferred until the design has been fully developed, maximum personnel doses may be approximated based on the goals defined above.

The test facility population during operations is expected to range up to 150 persons. Procedures would be followed to keep all exposures to on-station personnel ALARA. All personnel not required to execute the tests would be evacuated from the facility during actual test events. However, a conservative approximation of the annual accumulated dose for all on-station personnel is as follows:

$$150 \text{ persons} \times 500 \text{ mrem/yr} = 75,000 \text{ person-mrem/yr.}$$

Over a 10-year operating period this corresponds to consequences less than 750,000 person-mrem. This estimate applies to both candidate locations, NTS and INEL.

The goal of the PBR technology development program is to maintain exposures to on-site, non-program related personnel (i.e., those workers involved with other activities at NTS and INEL) to 20 mrem/yr. The daily worker populations at NTS and INEL are approximately 4,500 and 8,500, respectively. Thus, a conservative approximation of the annual accumulation of dose during normal operations would be

$$\text{NTS: } 4,500 \text{ persons} \times 20 \text{ mrem/yr} = 90,000 \text{ person-mrem/yr}$$

$$\text{INEL: } 8,500 \text{ persons} \times 20 \text{ mrem/yr} = 170,000 \text{ person-mrem/yr.}$$

Over a 10-year operating period this corresponds to a total exposure of 900,000 person-mrem at NTS, and 1.7 million person-mrem at INEL. This compares with a 10-year total dose to the same groups of workers of nearly 19 million person-mrem at NTS and 37.5 million person-mrem at INEL due to natural radiation exposure.

Test Accidents

On-station personnel would be at risk in the event of test facility accidents, both industrial and radiological. The risks would be minimized by adherence to all applicable safety standards and special guidelines for the construction, operation, and decommissioning of such facilities; in all its phases, the PBR technology development program is committed to reducing all risks to ALARA levels. During test operations, when potential risks or accidental radiological exposures are greatest, all unnecessary personnel would be evacuated from the facility. Those who must remain on-station would be housed in a conservatively designed control bunker until the test is completed and the hazard is reduced to an acceptable level.

Doses to on-site workers following an accident can be estimated using the bounding Consequence II "Late" accident calculation. Except for distances less than approximately 3 miles from the release point, this accident bounds all others (the Consequence III accident is somewhat larger closer in).

Acute population dose at NTS is estimated assuming most workers reside at Mercury. For conservatism, the entire worker population of 4,500 is placed there, since the Consequence II "Late" accident dose peaks at approximately 30 kilometers, which is roughly the distance from SMTS to Mercury. At NTS the acute population dose at Mercury was determined to be 458,000 person mrem to the exposed worker population. Since Mercury lies at the peak dose distance of approximately 25 to 30 kilometers from the SMTS release point, the estimated peak acute dose to any worker would not exceed 200 mrem. The average acute dose to the exposed worker population is evaluated as approximately 102 mrem.

The acute population dose at INEL is estimated based on approximately 8,500 workers. Acute population dose at INEL peaked in the west-southwest (WSW) direction with a magnitude of 316,000 person-mrem exposing a population of 3,222. The exposed worker population resides between 10 and 30 kilometers from the release point and would receive peak acute doses of no more than 200 mrem. The average acute dose to the exposed worker population is approximately 98 mrem.

4.12.3 Nonradiological Hazards

4.12.3.1 Construction. The design of the test facility has no known features that would increase worker hazards during construction. Site characterization would be conducted at both the SMTS and the CTF prior to construction, and any chemical and/or radiological contaminants present would be identified. Any remediation required to make the site safe for personnel and operations would be performed before PBR technology development construction activities could begin (see Section 4.5). Because construction activities would be performed in compliance with applicable

worker safety codes (e.g., OSHA, National Electric Code, National Fire Protection Code, DOE), and because no occupational hazards, beyond those currently experienced during other construction activities at NTS or INEL (e.g., heavy equipment hazards, overhead and lifting hazards, trenching and shoring hazards and other construction hazards) have been identified, no significant non-radiological impacts, such as exposure to site contaminants, are expected to occur.

4.12.3.2 Operations. The proposed use of cryogenic materials such as LH_2 , liquid oxygen (LOX), gaseous and liquid nitrogen, and gaseous helium introduces several potential hazards.

Due to the extremely low temperature of cryogenic fluids, exposure may cause burns and tissue damage to the skin (Sax, 1984). The extremely cold temperatures may cause condensation of air, which can enrich the local oxygen content, increasing the possible violence of fires (especially in the presence of hydrogen).

If the storage systems are not properly purged following a handling operation, heat expansion of cold gases may cause system ruptures. This is compounded in the case of liquid hydrogen, where oxygen crystals can be formed in the fluid as a result of unpurged air in the system, resulting in a detonatable mass. Because of these hazards, there must be provision for venting in any potential fixed volume where cryogenic fluids might collect.

Hydrogen Safety

LH_2 is colorless and odorless as both a liquid and gas (Air Products and Chemicals, 1990a). It is classified as a simple asphyxiant from a health hazard perspective because, in high enough concentrations, it can displace air, causing asphyxiation to workers in a contained environment. It is not an inhalation hazard or listed as a carcinogen and has no Threshold Limit Value, Permissible Exposure Limit, or Emergency Exposure Guidance Limits as defined by the American Conference of Governmental Industrial Hygienists, OSHA, and the National Research Council, respectively (Air Products and Chemicals, 1990a; Federal Emergency Management Agency et al., 1989). The principal hazard associated with LH_2 is its extreme flammability range (4.0 percent Lower Flammability Limit to 74.2 percent Upper Flammability Limit); hydrogen requires little energy to ignite a gas mixture, and burns with an almost invisible flame. Once ignited, the flame will travel rapidly through a hydrogen mixture and explosions can occur.

Hazards. Hydrogen would be required during PBR propulsion technology assessment in two forms, gaseous and liquid, and would be contained in multiple storage tanks at the ground test facility. Large quantities of gaseous hydrogen have been used at industrial and rocket facilities for a number of years and a review of hydrogen safety literature regarding bulk

storage and operations (Edeskuty, 1991) does not identify any extraordinary safety requirements for use and handling in an industrial environment.

Storage/Handling. The hydrogen system would be designed, operated, and maintained in accordance with all appropriate NFPA, CGA, and ASME standards to ensure sufficient protection for personnel. Additional safety measures would also include a shrapnel barrier to reduce the possibility that shrapnel generated by a nearby explosion would impact the hydrogen storage tanks. Generally, when a system ruptures, the proportion of combustible fuel in the spill is less than ten percent of the total quantity spilled, so if a rupture should occur, only a portion of the theoretical maximum explosive potential would be available because high-energy explosions require a well-mixed oxygen-hydrogen environment. Also, although gaseous hydrogen forms a combustible mixture very quickly, it is also very buoyant and the hazard will therefore exist for a relatively shorter time than, for example, with a methane or gasoline spill (McCarty et al., 1981). Although the deflagration (flame speed below the speed of sound) and/or detonation (flame speed above the speed of sound) of hydrogen would cause a potential threat to the health and safety of on-site personnel, proper system design, storage, and handling would significantly reduce that danger.

Oxygen Safety

LOX is pale blue, gaseous oxygen is colorless (Air Products and Chemicals, 1989), and both are odorless. Breathing an extremely high concentration of oxygen (60 percent or greater) can produce central nervous system effects. There are no workplace or emergency limits for oxygen (Air Products and Chemicals, 1989). Atmospheric oxygen contents greater than 25 percent are considered severe fire hazards. Although oxygen itself is nonflammable, it vigorously supports and accelerates combustion of flammable materials. Normal oxygen content of the atmosphere at sea level is 20.8 percent by volume. Some materials that are considered to be noncombustible in air readily burn in the presence of pure oxygen. Guidelines set by the National Institute of Health and Safety recommend the oxygen content in air be maintained between 19.5 and 25 percent by volume. Environments with an atmospheric oxygen content of less than 19.5 percent are considered oxygen deficient and cannot support the requirements of human respiration.

Hazards. Three potential dangers must be considered in relation to oxygen storage. Like LH_2 , the extremely low temperatures of LOX may cause burns and tissue damage in the event of skin contact. Second, LOX readily supports combustion of oxidizable material, and is quickly absorbed by combustible materials (including clothing). In the presence of high concentrations of oxygen, many materials may quickly and violently ignite (Kirk-Othmer, 1986). Third, when LOX vaporizes at standard atmospheric conditions, the gas would take up 860 times as much space as the liquid.

Should this happen in an un-vented enclosed space, a high pressure explosion could occur (Kirk-Othmer, 1966). Leaks of oxygen from a storage system are especially dangerous in the presence of a highly combustible material such as hydrogen, which would also be stored at the ground test facility (NFPA, 1986; Sax, 1984).

Storage/Handling. LOX would be separated from the hydrogen storage area and, as with hydrogen, would be protected by a barrier designed to prevent impact to storage tanks from shrapnel. The pipes carrying the oxygen would also be insulated to prevent contact burns. Although the storage of oxygen would cause a potential threat to the health and safety of on-site personnel, locating the tanks away from the hydrogen storage area, along with proper storage and handling techniques would minimize that danger.

Nitrogen and Helium Safety

Hazards. Both liquid and gaseous nitrogen, and gaseous helium are colorless and odorless (Air Products and Chemicals, Inc., 1990b, 1990c). They are considered to be simple asphyxiants as they can displace air to levels insufficient to support life. No workplace or emergency limits have been established for nitrogen or helium (Air Products and Chemicals, Inc., 1990b, 1990c; Federal Emergency Management Agency et al., 1989). Nitrogen and helium are classified as nonflammable and nonexplosive.

Helium is an inert gas that will not react with any other material and will neither burn nor support combustion. Nitrogen is nearly as inert as helium, and in almost all instances will not react to support combustion reactions.

Storage/Handling. Tanks of helium and nitrogen would be stored in accordance with accepted industrial practices and would also be protected by a barrier to prevent accidental impacts from shrapnel. The primary hazard from tank rupture would be a sudden release which could displace oxygen and serve as an asphyxiant. Although storage of helium and nitrogen would expose on-site personnel to conditions that could threaten health and safety, proper storage and handling would minimize that danger.

Transportation of Cryogenic Materials

Cryogenic liquids would be produced at commercial manufacturing plants and transported to SMTS or CTF by either rail car or tanker truck. In either case transport would take place in specially designed containers, which would maintain the fluids at proper cryogenic conditions (low temperature, correct pressures, etc.). The hazards associated with transportation of cryogenic materials may result from:

- Tanker/railcar preparation, testing, and filling at the producer's site

- Vehicle/engine malfunction, road conditions, traffic situations or driver error
- Cargo leakage en route
- Delivery of the cargo at the user's site, the preparation of the tanker/railcar for return, and the return trip.

Transportation of cryogenic materials is conducted commercially on a regular basis, and is considered to be a routine operation for manufacturers. Normal transportation (i.e., no accidents) of cryogenic materials presents no safety hazards to the public.

Effluent Treatment System

There are three potential safety hazards associated with the ETS used to treat the exhaust from PIPET and GTA testing. First, air may enter the system, mix with hydrogen, and cause deflagration and/or detonation; hydrogen deflagration and/or detonation within, or adjacent to, the ETS may cause serious damage and/or loss of life. Second, leaks may develop, allowing hydrogen to escape into the atmosphere where ignition and subsequent deflagration and/or detonation could also occur. Third, the flare may extinguish, causing a safety hazard as the unburned hydrogen accumulates and creates an explosive atmosphere external to the system.

To prevent infiltration of air into the system, a complete purge using gaseous helium will be accomplished prior to the start of a test operation. This purge will ensure that a helium atmosphere will displace any oxygen in the system.

Monitoring will be accomplished during test operations to detect any hydrogen leaks. Prior to test operations, the system will be thoroughly inspected to detect any possible points where leakage may occur, with special attention given to valves, pipe joints and other pipe-fit locations.

To safeguard against extinguishment of the flare, it would be equipped with a redundant propane pilot light to ensure that the hydrogen is combusted as it exits. All non-essential personnel would be restricted from the site and operational personnel would be confined to the central bunker during test operations. Even though all safety procedures would be followed, operation of the ETS would be considered a potential threat to the health and safety of on-site personnel.

4.12.3.3 Site-Specific Considerations

SMTS

No additional health and safety hazards have been identified that are unique to the SMTS.

CTF

In addition to the hazards shared with the SMTS, the CTF presents an additional hazard related to the use of the existing containment structure. The use of this structure for testing purposes may allow the build-up of hydrogen inside the facility during test operations. Following test completion, venting of the structure would be required before personnel could enter. This would prevent the potential for explosion due to ignition of explosive concentrations of hydrogen, or asphyxiation due to low oxygen levels. Because the use of the containment structure could threaten the physical well-being of workers, its use may have a moderate impact on safety.

4.12.3.4 Accidents

Cryogenic Transportation Accidents

Due to their low temperatures and extreme volatility, cryogenic fluids present a moderate to severe hazard potential in the event of a tanker truck accident during their transport from a manufacturing plant to the PBR propulsion technology assessment site. Liquid hydrogen has been selected as presenting the greatest potential hazard, since it combines the hazards associated with low temperature liquids with the issue of flammability.

Accident scenarios for transporting LH_2 include leaks from vents and major damage to the vacuum shell, causing the container to rupture explosively. A methodology for use by communities performing emergency planning and response activities under Title III, Community Right-To-Know, is presented in the *Handbook of Chemical Hazard Analysis Procedures*. This can be used to perform hazard assessment, probability analysis, and consequence analysis, as is done in this section for LH_2 transportation (Federal Emergency Management Agency et al., 1989).

Probability Analysis. Frequencies of vehicular accidents for tanker truck and railcar transportation modes can be calculated using the *Handbook of Chemical Hazard Analysis Procedures*. The average accident rate for tanker trucks is a rate of one accident per 500,000 miles, and is representative of the general experience of trucks carrying hazardous materials throughout the United States. Railcar accident rates for a car that is part of a train on a mainline track (i.e., not in a yard, where accidents are more frequent) is one

accident per 1.6 million miles. These rates are conservative. As an example, one supplier of LH_2 has reported only one accident in 30 years that resulted in the venting of hydrogen. No injuries were reported in this accident. The frequency of various spill sizes was calculated by multiplying the accident frequency by a conservative value of 20 percent, indicating that of the accidents that occur, 20 percent would result in a spill or discharge. Out of ten spills, six are assumed to be a 10-percent cargo loss, two are assumed to be a 30-percent cargo loss, and the remaining two spills are assumed to represent a 100-percent spill.

Hazards Description. The *Handbook of Chemical Hazard Analysis Procedures* provides the Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE) model to estimate vapor dispersion, fire, and explosion impacts associated with releases of hazardous materials. (Federal Emergency Management Agency et al., 1989). The ARCHIE model is used by communities with emergency planning responsibilities to evaluate accident consequences, and it is used here to compare the consequences of slow and fast (total) discharges for both modes of transport (rail and truck). A slow discharge is one in which a hole or other breach of the tanker allows the leakage of at this LH_2 at a rate of only 100 gallons per minute. At this rate, it will take more than 30 minutes for the entire tank contents to be lost. A fast discharge is one in which the entire tank contents are lost in the first 5 minutes following the accident.

Three types of accident consequence situations have been selected for analysis. These represent the maximum case events which may occur following release of LH_2 . These are:

- Pool fire: a released pool of LH_2 is ignited and burns across the pool surface
- Unconfined Vapor Cloud Explosion: a rapid ignition of the hydrogen vapor cloud above an LH_2 pool occurs, causing the flame speed to exceed the speed of sound, and thus expand rapidly
- Fireball: an ignition of the hydrogen vapor cloud above an LH_2 pool occurs, the flame speed is below the speed of sound, resulting in an expanding, burning vapor cloud.

Table 4.12-11 provides summary data from the ARCHIE analysis. This table shows the size of zones of effect for various consequences (pool fire, vapor cloud explosion, fireball) from both slow and total releases, with total release in the presence of an ignition source considered to be a worst-case accident. These data indicate that the largest zones of fatality and injury are associated with a total release railcar spill. However, the probability of a railcar spill is much lower than a tanker truck spill. Therefore, railcar

Table 4.12-11. Comparative Data on the Consequences of Four Accident Scenarios

	Tanker Truck Spill (Slow Release) (feet)	Tanker Truck Spill (Total Release) (feet)	Railcar Spill (Slow Release) (feet)	Railcar Spill (Total Release) (feet)
Pool Fire				
• Fatality Zone	31	88	44	315
• Injury Zone	45	126	63	451
Unconfined Vapor Cloud Explosion^(a)				
• Fatality Zone	26	77	31	140
• Injury Zone	142	410	162	742
• Property Damage Zone ^(b)	381	1,097	433	1,990
Fireball				
• Fatality Zone	218	218	218	218
• Injury Zone	466	466	466	466

Notes: (a) All distances are radii except for the vapor cloud explosion. The distance values for the vapor cloud explosion are in distance from the explosion, which can occur anywhere within the ground area passed over by the cloud or plume.

(b) Property damage defined as some damage to home ceilings; 10 percent window breakage.

transport generally can be considered to be the safer transportation alternative.

Cryogenic Storage and Handling Accidents

Several possible hazards may result from accidents involving the storage and on-site transfer of cryogenic materials. These include:

Spills from Off-loading and Storage. Any leak or spill of a cryogen could result in immediate damage to living tissue due to the extremely cold temperatures at which these materials are stored. Leaks of hydrogen or oxygen could lead to fires or explosions in the presence of ignition sources or organics. Once mixed with an oxidizer and ignited, hydrogen gas can burn as a deflagration in which the flame travels through the cloud at subsonic speeds. A hydrogen cloud can also detonate; that is, the flame and resulting shock wave travel at supersonic speeds. GH_2 diffuses rapidly over large areas. When LH_2 spills, its extremely low temperature immediately allows it to act as other liquids by pooling in the spill area. As the liquid heats above its boiling point, it evaporates as a relatively cold gas, (i.e., as compared to the air temperature). At this point, GH_2 would be heavier than air. As GH_2 continues to be warmed by the air, the cloud over the spill would become buoyant, allowing it to rapidly dissipate in an unconfined environment. Hydrogen diffuses rapidly if not confined. A spill

of 500 gallons (1.9 cubic meters) of gaseous hydrogen may diffuse to nonexplosive limits within 1 minute if spilled outdoors (Ordin, 1988). Leaks of these materials into confined spaces could displace air, possibly resulting in injury or fatalities. Small releases of hydrogen gas from piping and storage vessels are expected in cryogenic facilities. Consequently, flares, detection systems, control/prevention of all potential ignition sources, and contingency planning for emergencies are a routine part of the design and operation for such facilities.

Explosion in the Storage Facilities. The maximum-case accident scenario for the cryogenic facilities would be explosion following hydrogen leakage from a storage dewar into a confined space, causing a material failure in a large storage vessel. This could result in a larger detonation affecting the LOX and other facilities in the immediate area. The blast wave, thermal effects, and flying debris would undoubtedly cause extensive property damage and fatalities in the immediate area, as shown in Table 4.12-12. LH_2 , LOX, LN_2 , and He do not produce toxic combustion products, but combustion of the materials in the surrounding area could produce unknown constituents. If the LN_2 facilities became involved in the accident, nitrogen oxides could be produced due to the high temperatures of the detonation. The potential hazard to the public from such an event would be the cloud of combustion products formed.

Table 4.12-12. Damage Distances from Single Dewar Accident

Threshold	Distance (kilometers)
1% Window Breakage	19.5
Safe Inhabited Building Distance	1.5
Safe Public Road Distance	0.825
1% Ear Drum Rupture	0.525
1% Death	0.2

Hydrogen Flare Stack. Fire and explosions have occurred in flare stacks (Ordin, 1988). The design of a hydrogen disposal system must (1) ensure that the flare stack is situated for safe disposal relative to other facilities and personnel, (2) prevent explosions from hydrogen contamination with air inside the stack, flame blowout, or low flows, and (3) ensure that thermal radiation flux levels due to the burning hydrogen do not affect operations in the immediate area. Should system failure cause an explosion, the relatively small amounts of hydrogen present in the flare stack in comparison with that in a storage dewar ensures that the explosion would be considerably

less energetic. The area affected by such an explosion would be much smaller than a dewar explosion and would be much less significant.

Beryllium Release

The PIPET and GTA assemblies may contain beryllium metal as part of the core moderator, which may become airborne in a catastrophic failure. In the event of an accident in which core integrity is lost there is the potential for some or all of this beryllium to be released, where exposure due to inhalation is possible. However, no credible accident scenario is conceivable which could produce a total disruption of the core and release considerable amounts of beryllium. This includes consideration of hydrogen fire and explosion, which was found to be insufficiently energetic to mobilize significant quantities of beryllium.

For conservatism, an analysis of the consequences of a complete beryllium release was performed. Details of this analysis can be found in Appendix E, Section 6.0. Results of this analysis indicate that even in the case of a complete release of beryllium from a GTA core (the maximum case), total exposure to any individual will be no greater than 0.0003 milligrams, which is more than 50 times less than the 0.0173 mg daily exposure allowable under OSHA permissible exposure limits for occupational workers.

4.12.4 Mitigation Measures

During normal operations and radioactive material transport, no mitigation measures would be required since impacts will be well below regulatory thresholds, and will be very small relative to the existing natural radiation environment. In the event of an accident during reactor operation, several measures can be taken to reduce the impacts, these include:

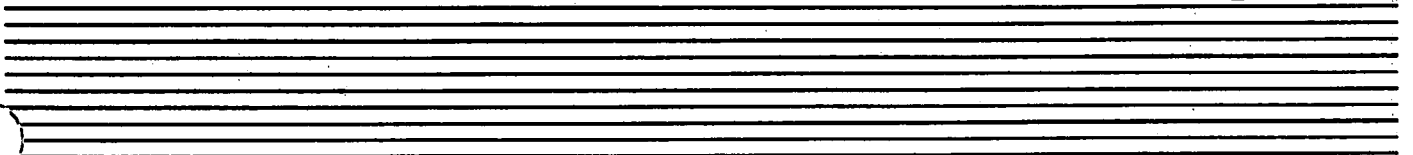
- Isolate affected areas downwind of SMTS or CTF to limit exposure to personnel and the public. This can be accomplished through road closure and/or evacuation of populations in accordance with pre-established accident response plans.
- Restrict use of land contaminated as a result of an accidental release. Restrictions could include limitations on allowable activities (e.g., no grazing or agriculture). Restrictions would reduce long-term dose resulting from resuspension inhalation, groundshine, and ingestion of contaminated food products. It would also act to prevent migration of contamination to non-restricted and unaffected areas.
- Decontaminate to reduce the need for long-term land use restriction.

Mitigation of effects due to transportation accidents would be similar to those cited above. However, because affected areas would be much smaller, immediate evacuation followed by decontamination efforts would be favored, which would significantly reduce impacts resulting from accidents below evaluated levels.

4.12.5 No-Action Alternative

Since no activities or uses of radiological, hazardous, or cryogenic materials would occur with the No-Action Alternative, no health and safety related impacts would occur at either of the SNTP alternative sites or along any transportation routes.

Chapter 5



5.0 CONSULTATION AND COORDINATION

Federal and state agencies that were contacted during the course of preparing this environmental impact statement are listed below.

Federal Agencies

U.S. Department of Agriculture, Soil Conservation Service
U.S. Department of Interior, Fish and Wildlife Service
U.S. Department of Interior, National Park Service
U.S. Department of Energy

State Agencies

Nevada Bureau of Air Quality
Nevada Fish and Game Department
Nevada Wildlife Department
State Office of Historic Preservation (Nevada and Idaho)

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Chapter 6



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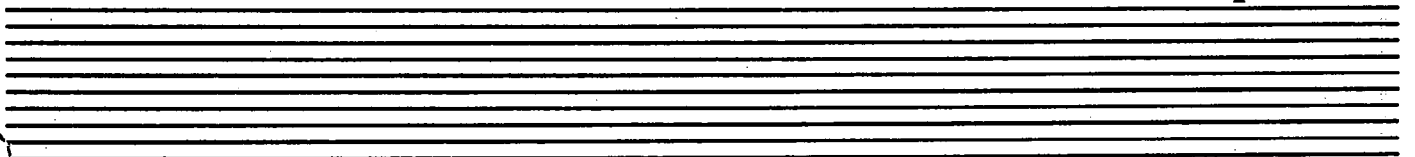
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Chapter 7



7.0 REFERENCES

- Abrahamson, S. et al., 1989. Health Effects Models for Nuclear Power Plant Accident Consequence Analysis, Sandia National Laboratories report NUREG/CR-4214, SAND85-7185, Rev. 1, Part II, Albuquerque, New Mexico, May.
- Adams, J., 1989. Memo regarding TSA Operation of Induction Furnace in Lab E-6, Brookhaven National Laboratories, July 14.
- Advisory Council on Historic Preservation, 1991. Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities, Washington, DC, February.
- Air Products and Chemicals, Inc., 1989. Oxygen Material Safety Data Sheet, Industrial Gas Division, Allentown, Pennsylvania, February.
- Air Products and Chemicals, Inc., 1990. Hydrogen Material Safety Data Sheet, Industrial Gas Division, Allentown, Pennsylvania, March.
- American Nuclear Society, 1977. American National Standard Research Reactor Site Evaluation, August 1977.
- American Nuclear Society, 1986. Glossary of Terms in Nuclear Science and Technology.
- Anderson, E.R., 1989. Memo regarding NOI #029A Expansion to the 30 Weaving Carbon/Carbon Facility, Hercules, February 17.
- Aquilina, N.C., 1989. Memo regarding Nuclear Testing Restrictions and Guidance, DOE Nevada Operations Office, November 22.
- Atwood, D.J., 1989. Deputy Secretary of Defense, memo to the Chairman of the House and Senate Appropriations Committees, May 17.
- Babcock & Wilcox, 1985. Lynchburg Research Center Environmental Report, October.
- Babcock & Wilcox, 1988. Task 2 Fuel Development, May 19.
- Babcock & Wilcox, 1989a. B&W Technical Proposal Volume I, May 22.
- Babcock & Wilcox, 1989b. Prospectus for High Temperature Fuel Kernel Development Program, July 6.
- Babcock & Wilcox, 1989c. PIPE-II Test Results, August 15.
- Babcock & Wilcox, 1991. Input for Environmental Report Items 1-6, January 18.

- Baker, S., 1991. Memo regarding Regulations for Radioactivity, Dames & Moore, April 23.
- Barletta, R.E. et al., 1989. Materials Compatibility and Diagnostic Test Development, June.
- Benjamin, B.C., 1991. SMTS Preliminary Safety Analysis Report Chapter 2, March 7.
- Bergdale, G., 1991. Telephone conversation between Garlan Bergdale and Ron Kear regarding the Desert Tortoise.
- Bergstrom, A.J., 1991. Memo regarding Hercules Facility Response for EIS, Hercules, February 4.
- Biological Effects of Ionizing Radiation (BEIR), 1972. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, Biological Effects of Ionizing Radiation (BEIR), National Research Council, National Academy of Sciences, Washington, DC.
- Biological Effects of Ionizing Radiation (BEIR), 1980. BEIR III, Biological Effects of Ionizing Radiation (BEIR), Division of Medical Sciences, Assembly of Life Sciences, National Research Council, National Academy of Sciences, Washington, DC.
- Biological Effects of Ionizing Radiations (BEIR), 1990. Health Effects of Exposure to Low Levels of Ionizing Radiation BEIR V, BEIR V, National Research Council, Washington, DC, 1990.
- Brookhaven National Laboratory, 1989. Material Control Plan for Materials Compatibility Studies, February.
- Brookhaven National Laboratory, 1990. Brookhaven National Laboratory Safety Manual, November.
- Brookhaven National Laboratory, 1991. Response to Baseline and Program Questions, February 12.
- Brown, T.L., Hazards Associated with Hydrogen Fuel, 11th Intersociety Energy Conservation Engineering Conference Proceedings, ASME, New York.
- Bureau of National Affairs, Environmental Reporter, Section 151 - Radiation.
- Carson, R.W., 1991a. Memo, regarding Information Relative to the Shipments Involved with the Program, Babcock & Wilcox, January 4.
- Carson, R.W., 1991b. Memo regarding B&W Baseline Information, Babcock & Wilcox, January 11.
- Carson, R.W., 1991c. 1991 DQPAA Information, Babcock & Wilcox, February 22.
- Chelton, D.B., 1964. Safety in the Use of Liquid Hydrogen, Technology and Uses of Liquid Hydrogen, pp. 359-378, The MacMillian Company, New York.

Christenson, G.E. and C. Purcell, 1985. Correlation and Age of Quaternary Alluvial-Fan Sequences, Basin and Range Province, Southwestern United States, Geological Society of America Special Paper 203.

Clark, J., Viessman, and M. Hammer, 1971. Water Supply and Pollution Control.

Clayton, G.D., and F.E. Clayton (eds.), 1981. Patty's Industrial Hygiene and Toxicology, John Wiley & Sons, Inc.

Colorado Vital Statistics Annual Report (Colorado), 1989.

Compressed Gas Association, 1986. Hydrogen.

Conservation and Natural Resources, Department of, 1990. Report indicating that significant historic or archeological sites were not discouraged at area 14 of NTS, December 28.

Costa, C.F., 1989. Offsite Remedial Action Capability for Underground Nuclear Weapons Test Accidents, Environmental Monitoring Systems Laboratory - Las Vegas U.S. EPA, November.

Croessmann, C.D., 1991. Memorandum regarding the Estimate of PIPET Weight. Sandia National Laboratories, August 26.

Croff, A.G., 1983. ORIGEN2: Versatile Computer Code for Calculating The Nuclide Compositions and Characteristics of Nuclear Materials, Nuclear Technology Vol. 62, September.

Davis, R.E., 1988. Memo regarding Graphite Furnace Project Review, Brookhaven National Laboratories, October 10.

Department of Commerce, U.S., n.d. Climatology of the INEL 2nd Edition.

Department of Defense, U.S., 1969. U.S. Departments of the Army, the Navy and the Air Force. Structures to Resist the Effects of Accidental Explosions, TM 5-1300, NAVFAC P-397, and AFM 88-22, June.

Department of Defense, U.S., 1991. Ammunition and Explosives Safety Standards, DOD 6055.9-STD, Change No. 3, Assistant Secretary of Defense - Force Management and Personnel, January 25.

Department of Energy, U.S., Phone Conversation between Stacey Sorg, Program Manager for Defense Low Level Waste for DOE/NVO, and John Maroney, Dames & Moore.

Department of Energy, U.S., 1977a. Loss of Fluid Test (LOFT) Integral Test System Final Safety Analysis Report, (3 volumes), August.

Department of Energy, U.S., 1977b. Nevada Test Site Final Environmental Impact Statement.

- Department of Energy, U.S., 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, Washington, DC.
- Department of Energy, U.S., 1984a. INEL Environmental Characterization Report Volume I-Summary, September.
- Department of Energy, U.S., 1984b. INEL Environmental Characterization Report Volume II-Appendices A-C, September.
- Department of Energy, U.S., 1984c. INEL Environmental Characterization Report Volume III-Appendices D-H, September.
- Department of Energy, U.S., 1986. Yucca Mountain Site Nevada Research and Development Area, Nevada Environment Assessment, May.
- Department of Energy, U.S., 1988a. Final Environmental Impact Statement: Special Isotope Separation Project, DOE-EIS - 0136, Washington, DC, November.
- Department of Energy, U.S., 1988b. Office of Civilian Radioactive Waste Management Section 175 Report, December.
- Department of Energy, U.S., 1988c. Nevada Test Site Radiation Safety Manual.
- Department of Energy, U.S., 1988d. Site Characterization Plan Yucca Mountain Site, Nevada Research and Development Area, Nevada, December.
- Department of Energy, U.S., 1988e. Environmental Regulatory Compliance Plan for Site Characterization. Yucca Mountain Site, Nevada Research and Development Area, Nevada, December.
- Department of Energy, U.S., 1989. Environmental Permits NTS Area 14 - Saddle Mountain, November 13.
- Department of Energy, U.S., 1990a. Nevada Test Site Annual Site Environmental Report - 1989, Volume 1, DOE/NV/1063-11, Las Vegas, Nevada.
- Department of Energy, U.S., 1990b. Idaho National Engineering Laboratory Site Environmental Report for Calendar 1989, June.
- Department of Energy, U.S., 1990c. Tiger Team Assessment of the Brookhaven National Laboratory, June.
- Department of Energy, U.S., 1990d. Nevada Operations Office (NVO), Environmental Status at the NTS - Annual Site Environmental Report for Calendar Year 1989 and Environmental Compliance Self Assessment.

Department of Energy, U.S., 1990e. INEL Site Characteristics Environments, November 16.

Department of Energy, U.S., 1990f. DOE Explosives Safety Manual, May.

Department of Energy, U.S., 1991a. Draft Environmental Impact Statement for the Siting Construction, and Operation of the New Production Reactor Capacity, April.

Department of Energy, U.S., 1991b. Radiation Protection Standards for External and Internal Exposures, April 29.

Department of Energy, U.S., 1991c. Nuclear Weapons Complex Reconfiguration Study, Report No.: DOE/DP-0083, January.

Department of Energy, U.S. Idaho Operations Office, n.d. The OECD LOFT Project.

Department of Energy Nevada Operations Office, U.S., 1988a. DOE/Nevada Emergency Preparedness Plan, May.

Department of Energy Nevada Operations Office, U.S., 1988b. Nevada Test Site Defense Waste Acceptance Criteria Certification and Transfer Requirements, October.

Department of Energy Nevada Operations Office, U.S., 1990a. Fourteenth Monthly Environmental Compliance Action Report, August.

Department of Energy Nevada Operations Office, U.S., 1990b. Planning and Operations Directive Underground Nuclear Test Operations, October 11.

Department of Energy Nevada Operations Office, U.S., 1990c. Mixed Waste Disposal Operation at the Nevada Test Site Nye County, Nevada, January.

Department of Transportation, U.S., 1984. Accidents of Motor Carriers of Property, Washington, DC.

DOE, see Department of Energy, U.S.

DOE/NV, see Department of Energy Nevada Operations Office

Doull, J., C.D. Klaasen, and M.O. Amdur, 1980. Casarett and Doull's Toxicology, Macmillan Publishing Co., Inc.

Dunning, D.E., 1976. Estimates of Internal Dose Equivalent from Inhalation and Ingestion of Selected Radionuclides, WIPP-DOE-176.

Eckerman, K.F., A.B., Wolbarst, and C.B., Richardson, 1988. Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, September.

Edeskuty, F.J., 1964. Liquid Hydrogen as a Coolant/Propellant for Nuclear Rockets, Technology and Uses of Liquid Hydrogen, pp. 181-194, the MacMillian Company, New York.

Edeskuty, F.J., 1991. Safety in Cryogenic Systems, Chapter 4 of Cryogenic Engineering, UCLA short course, May.

Edeskuty, F.J., and R. Reider, 1969. Liquified Hydrogen Safety - a Review, ASSE Journal, pp. 18-23, May.

EG&G Idaho, Inc., n.d. LOFT (Loss of Fluid Test), Idaho Operation Office.

Environmental Assessment Repair and Restoration of Space Launch Complex 4, Vandenberg AFB, CA.

Environmental Protection Agency, 1991a. Offsite Environmental Monitoring Report - Radiation Monitoring Around U.S. Nuclear Test Areas, Calendar Year 1989, June.

Federal Emergency Management Agency, U.S. Department of Transportation, and U.S. Department of Energy, 1989. Handbook of Chemical Hazard Analysis Procedures, Washington, DC.

Felty, J., 1991. Fax with input to chapter 4 for the EIS. DOE, September 5.

Fetter, S., 1988. Internal dose Conversion Factors for 19 Target organs and 9 Irradiation Times and External Dose-Rate Conversion Factors for 21 Target Organs for 259 Radionuclides produced in Potential Fusion Reactor Materials, EGG-FSP-8036, March.

Garrett Fluid System Division, 1991. Garrett Fluid System Division Environmental Report for Test Activities for the OTV Program, January 11 and January 28.

Glasstone, S. and A. Sesonske, 1981. Nuclear Reactor Engineering, Third Edition, Van Nostrand Reinhold Company, New York.

Greaney, P., 1992. Telephone conversation between Dr. Greaney, Greaney Medical Group, and J. Moore, The Earth Technology Corporation, July 29.

Grumman Space and Electronics Division, n.d. EIS Evaluation Program Summary.

Grumman Space and Electronics Division, 1988. Phase II Program Integrator, 1988.

Grumman Space and Electronics Division, 1991. Grumman Facility Description for EIS. July 22.

GSSD, SNL, B&W, BNL, ASAC, ATC, 1989. Responses to DOE Assessment Report, March 17.

Hardinger, D., 1990. Socioeconomic Database for Southeastern Idaho, EG&G Idaho, Inc., April.

Harmon, C., 1990. Letter regarding Internal Communication by the DOE/NVO Referencing the Desert Tortoise Endangered Species Act Compliance, Sandia National Laboratories, November 13.

Harmon, C., 1991a. Memo regarding Hydrogen Safety Problems, Sandia National Laboratories, January 7.

Harmon, C., 1991b. Response to Comments on DOPAA and Other Outstanding Action Items.

Harmon, C., 1991c. Preliminary Response Comments in Reference to Task 13 Description of Proposed Actions and Alternatives, Sandia National Laboratories, February 11.

Harmon, C., 1991d. DOPAA Input Pertaining to GTAs and QTAs, Sandia National Laboratories, March 5.

Harmon, C., 1991e. Comments in response to the 29 April 1991 Preliminary Draft Environmental Impact Statement, Sandia National Laboratories, June 10.

Harmon, C., 1991f. Letter regarding Information on Hydrogen Cool-Down Time, Fuel Element, Helium, and Bulk LLW, June 12.

Harmon, C., 1991g. Proposed Replacement for the Process Fluids System, Sandia National Laboratories, July 5.

Harmon, C., 1991h. Information regarding shipment of hazardous but nonradioactive waste, Sandia National Laboratories, June 24.

Harmon, C., 1991i. Record of Conversation between Harmon & Denes, re: EIS information. Sandia National Laboratories, July 18.

Harmon, C., 1991j. Record of Conversation between Harmon & Denes, re: Treatment of ETS effluent. Sandia National Laboratories, September 3.

Haslett, R.A., 1989. Safety Strategy, Grumman Space Systems, November 15.

Hill, Thomas, Principal Program Specialist, Idaho National Engineering Laboratory
B.S., 1967, Mechanical Engineering, Washington State University
Years of Experience: 25

Hipp, J., 1990. Memo regarding information on Dose vs Distance, S-Cubed, September 13.

Holzworth, G.C., 1972. Mixing Heights, Wind Speeds, and potential for Urban Air Pollution throughout the Contiguous United States, January.

Horan, J., 1990a. Memo regarding program Environmental Responses, Information on 1) Safety Policy; 2) Aerojet; and 3) GFSD/San Tan, Garrett Fluid System Division.

- Horan, J., 1990b. Material to be Used for the DOPAA, Grumman, November 8.
- Horan, J., 1990c. Material Experiments Conducted by the Ludwig Group, Grumman, November 12.
- Horan, J., 1991a. PBR Applications EIS, Grumman Space Systems, January 24.
- Horan, J., 1991b. Criticality Prevention D&D, Grumman Space Systems, January 29.
- Horan, J., 1991c. Response to Action Items Originating from EIS Meeting 5/22 and 5/23, Grumman, June 24.
- Horan, J., 1991d. Memo regarding Industrial Safety, Grumman, July 17.
- Horan, J. and M. Solon, 1991a. Response to Action Items as Result of the Review Meeting, Grumman Space & Electronics Division, February 1.
- Horan, J. and M. Solon, 1991b. Memo regarding DOPAA Revisions, Grumman Space and Electronics Division, February 26.
- Hord, J., 1976. Is Hydrogen Safe?, NBS Technical Note 690, U.S. Department of Commerce, October.
- Hord, J., 1978. Hydrogen Safety: An Annotated Bibliography of Regulations, Standards and Guidelines, Hydrogen Energy System, Vol. 4, pp. 2247-2257, Ed. by T.N. Verziroglu and W. Seifritz, Pergamon Press, Oxford.
- Idaho National Engineering Laboratory, 1986a. Idaho National Engineering Laboratory, History of Facilities and Programs.
- Idaho National Engineering Laboratory, 1986b. Idaho National Engineering Laboratory Around Report.
- Idaho National Engineering Laboratory, 1989. Idaho National Engineering Laboratory 2nd Edition. December.
- Idaho National Engineering Laboratory, 1990. Test Area North Site Characteristics, November 16.
- Idaho National Engineering Laboratory, 1991. 1990 Population Data for INEL, NWCRS-INEL.
- Idaho State University, 1986. Archaeological Investigations on the Idaho National Engineering Laboratory 1984 - 1985, August.
- Idaho State University, 1987. Archaeological and Paleontological Survey of the INEL for the SSC NEPA Compliance Plan, December.

- International Commission on Radiological Protection, 1979. Limits for Intakes of Radionuclides by Workers, ICRP Publication 30, Pergamon Press, New York.
- International Commission on Radiological Protection, 1983. Radionuclide Transformations - Energy and Intensity of Emissions, ICRP Publication 38, Pergamon Press, New York.
- Kato, W.Y., 1989. Memo regarding The DNE Safety Committee, Brookhaven National Laboratories, October 20.
- Kirk-Othmer, 1966. Encyclopedia of Chemical Technology, Vol. 14., John Wiley and Sons, New York.
- Krieger, G., 1991. Telephone conversation between Gary Krieger, M.D. and James Langsted, September 5.
- Lamarsh, J. R., 1983. Introduction to Nuclear Engineering, Second Edition, Addison-Wesley Publishing Company, Reading, Massachusetts.
- Leppert, J., 1991. Memo. "Information requested for EIS." DOE/NVO, July 18.
- London, M.P, n.d. Multi-Megawatt Preliminary Hazard Analysis, Grumman.
- Los Alamos National Laboratory, 1986. Experiences Gained from the Space Nuclear Rocket Program (ROVER), May.
- Los Alamos Scientific Laboratory, 1973. Nuclear Furnace-1 Test Report, March.
- McCarty, R.D., J. Hord, and H.M. Roper, 1981. Selected Properties of Hydrogen (Engineering Design Data) U.S. Department of Commerce.
- McCulloch, B., J. Mims, and J. Hipp, 1991. Memo regarding EIS Dose Calculation Input, Sandia National Laboratories and Advanced Sciences, Inc., March 20.
- Madsen, M. M., J.M. Taylor, R.M. Ostmeyer, and P. E. Reardon, 1986. RADTRAN III, SAND-84-0036, Sandia National Laboratories, Albuquerque, New Mexico.
- Mangold, F., 1991. Memo regarding The Applicability of Regulations and Regulatory Guidance to the Proposed Research Reactor, Dames & Moore, January 24.
- Mayernick, J., 1992. Memo from Dr. Mayernick, The Earth Technology Corporation, to B. Poll, The Earth Technology Corporation regarding: Calculation of Population Effect Rates, July 29.
- Monroe, L., 1991. Memo regarding Information on Air Quality Operating Permit, U.S. Department of Energy, February 4.

- Morgan, V., 1983. Archaeological Reconnaissance of Drill Hole Pad Ue14b (Nevada Coordinates N794100.57/E650100.55) and Access Road from Mine Mountain Junction to 16 - 02 Road. Desert Research Institute Cultural Resources Reconnaissance Short Report No. SR103183 - 1.
- National Fire Protection Association, 1986. Fire Protection Guide on Hazardous Materials. 9th edition, Quincy, MA.
- National Fire Protection Association, 1989a. Standard for Gaseous Hydrogen System at Consumer NFPA, 50a. 1989 Edition.
- National Fire Protection Association, 1989b. Standard for Liquefied Hydrogen Systems at Consumer Sites, NFPA 50b. 1989 Edition.
- National Geographic Society, 1983, Field Guide to the Birds of North America.
- National Council on Radiation Protection and Measurements, 1971. Basic Radiation Protection Criteria, National Council on Radiation Protection and Measurements report NCRP-39, Washington, DC.
- NCRP, see National Council on Radiation Protection
- Nelson, R., 1991a. Telephone conversation between Robert Nelson and Ann Leighton regarding waste issues. Idaho National Engineering Laboratory, August.
- Nelson, R., 1991b. Memo from Robert Nelson to Ronald Kear regarding water usage at INEL, August 27.
- Neuhauser, K.S., and F.L. Kanipe, 1991. RADTRAN 4, Executive Summary, SAND91-0776, (in preparation).
- NFPA, see National Fire Protection Association.
- North, Paul, 1991. Memo regarding Information for Task 13 Draft EIS Idaho National Engineering Laboratory (INEL), July 11.
- NRC, see Nuclear Regulatory Commission, U.S.
- Nuclear Weapons Re-Configuration Study, 1990.
- Nuclear Regulatory Commission, U.S., 1975. Office of Standards Development (OSD), Regulatory Guide, November.
- Nuclear Regulatory Commission, U.S., 1977. Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, Washington, DC, December.

- Nuclear Regulatory Commission, U.S., 1979. Environmental Standard Review Plans for the Environmental Review of Construction Permit Applications for Nuclear Power Plants. May.
- Nuclear Regulatory Commission, U.S., 1981. Office of Nuclear Regulatory Research (ONRR), Regulatory Guide, July.
- Nuclear Regulatory Commission, U.S., 1990. Office of Nuclear Regulatory Research (ONRR), MELCOR Accident Consequence Code System (MACCS), Version 1.5.11, NUREG/CR-4691, SAND86-1562, Washington, DC, February.
- Oak Ridge National Laboratory, 1990. MELCOR Accident Consequence Code System (MACCS), Code System for Calculation of Reactor Accident Consequences, RSIC Computer Code collection, CCC-546, NUREG/CR-4691.
- Ordin, P.M., 1974. Review of Hydrogen Accidents and Incidents in NASA Operations, 9th Intersociety Energy Conversion Engineering Conference Proceedings, ASME, New York, pp. 442-453.
- Parks, D., 1991. Memo regarding INEL Site Evaluation Criteria, Idaho National Engineering Laboratory, March 13.
- Parma, E.J., 1991. Memo, regarding Critical Assembly Activities, Sandia National Laboratories, January 7.
- Peterson, R.T., 1990. A Field Guide to Western Birds.
- Pflugel, G., 1988. Failure Modes and Effects Analysis, Babcock & Wilcox, June 22.
- Pippin, L.C., 1983. Four separate Class III Cultural Resources Surveys in Support of the Department of the Air Force's NH&S RDT&E Program, Nevada Test Site, Nye County, Nevada. Desert Research Institute Cultural Resources Reconnaissance Short Report No. SR032983-1.
- Pippin, L.C., 1986. An Overview of Cultural Resources on Pahute and Ranier Mesas on the Nevada Test Site, Nye County, Nevada, Desert Research Institute, Technical Report No. 49.
- Powers, D.A., 1988. Fission Product Behavior During Severe LWR Accidents: Modeling Recommendations for the MELCOR Code Systems, Vol 1: Fission Product Release from Fuel, NUREG/CR-4481, SAND85-2743, September.
- Raytheon Nevada Services, 1990. Title I - Engineering Design Summary Saddle Mountain Test Station, December.
- Reciniello, R., 1988a. Memo regarding Induction Furnace Experiment Using Hydrogen, Brookhaven National Laboratories, June 6.

- Reciniello, R., 1988b. Memo regarding RF Measurements, Induction Furnace, Building 703, Brookhaven National Laboratories, July 11.
- Reider, R., and F.J. Edeskuty, 1976. Hydrogen Safety Problems, 1st World Hydrogen Energy Conference, Proceedings, Vol. 3, pp. SC- 9 - 8C-14.
- Reynolds Electrical & Engineering Co., Inc., 1990. Emergency Management Master Plan, March.
- Rosen, B., V.H. Dayan, and R.L. Proffit, 1970. Hydrogen Leak and Fire Detection, NASA SP-5092, National Aeronautics and Space Administration.
- Sandia National Laboratories, 1977. Environmental Impact Assessment.
- Sandia National Laboratories, 1978. SPR Safety Analysis Report (SLA 74-0349). April.
- Sandia National Laboratories, 1981. ACRR Safety Analysis Report (SAND 77-0208). November.
- Sandia National Laboratories, 1989. Nevada Test Site Emergency Preparedness Plan, October 10.
- Sandia National Laboratories 1990a. Saddle Mountain Test Station, Facility Requirements Document Issue "A", April 5, 1991.
- Sandia National Laboratories 1990b. SMTS NTS, Draft Document #1 Environmental Source Document.
- Sandia National Laboratories, 1990c. Preliminary Safety Analysis Report Outline.
- Sandia National Laboratories, 1990d. MELCOR Accident Consequence Code System (MACCS), February.
- Sandia National Laboratories, 1991a. Letter to R. Kear from C. Ottinger regarding Transportation Analysis, June 19.
- Sandia National Laboratories, 1991b. Processing of SMTS Effluents, January 22.
- Sandia National Laboratories, 1991c. Seismic Response of the SMTS Site to the UGT Program at the NTS for the "BEXAR" event.
- Sandia National Laboratories, 1991d. Seismic Response of the SMTS Site to the UGT Program at the NTS for the "Montello" event.
- Sandia National Laboratories, 1991e. Transportation: Background Information and Analysis, January 8.
- Sauniere, J., and C. Tellier, 1983. Elements for an Hydrogen Safety Handbook, Hydrogen as an Energy Carrier, Proceedings of the 3rd International Seminar, pp. 421-430, D. Reidel Publishing Company, Dordrecht.

Sax, N.I., 1984. Dangerous Properties of Industrial Materials. Van Nostrand Reinhold Co., New York.

Schultz, M., 1990. Memo regarding GFSD Environmental Baseline for OTV Program at San Tan Facility, Allied Signal Aerospace Company GFSD, November 9.

Schultz, M., 1991. Record of Conversation between M. Schultz (GFSD), and A. Leighton (DMSS). September 17.

Science Applications International Corporation, 1990. Special Nevada Report.

Shefley, L.H., Jr, 1990. Increase in Air Pollution Permit Fees and a Schedule for processing of Prevention of Significant Deterioration Permits, Division of Environmental Protect, December 7.

Sherman, M.P., et al., 1985. The Effect of Transverse Venting on Flame Acceleration and Transition to Detonation in a Large Channel, Dynamics of Explosions, Vol. 106 Progress in Astronautics and Aeronautics, pp. 66-89, AIAA.

Sherman, M.P., S.R. Tieszen, and W.B. Benedick, 1989. FLAME Facility, The Effect of Obstacles and Transverse Venting on Flame Acceleration and Transition to Detonation for Hydrogen-Air Mixtures of Large Scale, NUREG/CR-5275, SAND85-1264, Sandia National Laboratories, Albuquerque.

Sherman, M.P., 1992. Internal Sandia memos from M.P. Sherman to R.L. Coats describing: Vented Bottle Model, March-April.

Shipers, L.R., 1991a. Memo regarding EIS Instrumentation and Control Philosophy, Sandia National Laboratories, March 18.

Shipers, L.R., 1991b. SMTS Subscale Facility Process Fluids System Requirements, May.

Shipers, L.R., 1991c. Memo regarding EIS information in response to 9 July 1991 memo. Sandia National Laboratories, July 18.

Smithsonian Institution, 1986. Handbook of North American Indians, Washington D.C., Volume 11, Great Basin.

SNL, See Sandia National Laboratories.

Solon, M., 1991. Memorandum from M. Solon (Grumman) to A. Rubis (DMSS) regarding Material Compatibility Questions. September 17.

Stewart, J.H., 1980. Geology of Nevada, Nevada Bureau of Mines and Geology, Special Publication 4.

Stewart, J.H., and J.E. Carlson, 1978. Geologic Map of Nevada, U.S. Geological Survey, 1:500,000.

The Harris Group, 1991. Site Narrowing Report Final Report, June.

Thomas, D.J., 1991. Communication EPA Population Census around Nevada Test Site, July 19.

Thome, D., Phillips, W. 1991b. Communication Regarding Nuclear Radiation Assessment Division, NTS, June 24.

Tieszen, S.R., et al., 1987. Detonability of H₂-Air-Diluent Mixtures, NUREG/CR-4905, SAND85-1263, Sandia National Laboratories, Albuquerque.

Turrin, B.D., et al., 1991. ⁴⁰Ar/³⁹Ar age of the Lathrop Wells Volcanic Center, Yucca Mountain, Nevada Science. Vol 253, p. 654-657, August 9.

U.S. Air Force, 1987a. Environmental Assessment Repair and Restoration of Space Launch Complex 4, Vandenberg AFB, CA, June.

U.S. Air Force, 1987b. Final Environmental Assessment: Air Force, Space Division, Beryllium Propellant Facility, Edwards Air Force Base, CA, February.

U.S. Air Force, 1990. Explosives Safety Standards, AF Regulation 127-100, August 3.

U.S. Atomic Energy Commission/National Aeronautics & Space Administration, 1971. Nuclear Rocket Development Station Nevada. December.

U.S. Department of Energy, Nevada Test Site, 1990. Standard Operating Procedures, NTS-SOP-5407, June 29.

U.S. Department of the Army, 1990a. Exoatmospheric Discrimination Experiment (EDX) Coordinating Draft Environmental Assessment, March.

U.S. Department of the Army, 1990b. High Endoatmospheric Defense Interceptor (HEDI) Draft Environmental Assessment, March.

U.S. Department of the Army, 1990c. Strategic Target Systems Environmental Assessment, July.

U.S. Department of the Interior, National Park Service, 1991. National Register Bulletin 15.

U.S. Fish and Wildlife Service, 1992. Letter to AFCEE/ESEP, Brooks AFB, Texas, June.

Van Nostrand Reinhold Company Regional Offices (VNRCRO), 1976. Van Nostrand's Scientific Encyclopedia.

Venetoklis, P., 1991. Applications & Benefits of the PBR to Military Missions, Grumman, July 15.

Vernon, M.E., 1990. PIPET Options, October 1.

Vernon, M., 1991. Material and Thermal Loading to the ETS in Core Dump Situation. Memo to L. Shippers, April 26.

Vest, G.D., 1991. Deputy Assistant Secretary of the Air Force, memo, Preliminary Draft Environmental Impact Statement Review Comments--Action Memorandum, May 21.

Walker, D.E., 1978. Indians of Idaho, University of Idaho Press, Moscow, Idaho.

Walton, L., 1989. Letter to V. Dandini, SNL, Comments on Safety Criteria Grumman 'A' Specification, Babcock & Wilcox, July 27.

Weatherford, L.G., Jr., n.d. Letter regarding R&D Program G FY-91 Statement of Work, Babcock & Wilcox.

Wright, S., 1991. Memo regarding Fission Product Release Estimates for the EIS, June 12.

XERAD, Inc., 1989. Updated (Final) IAG Report, June 30.

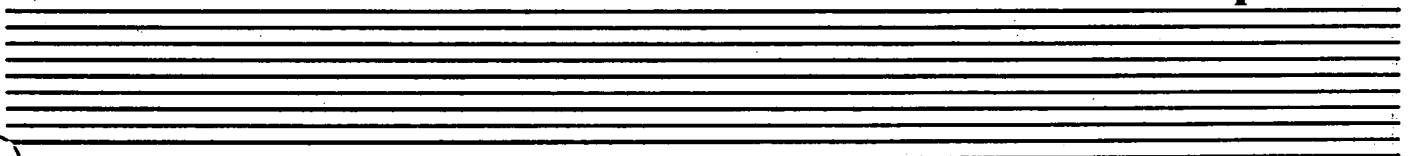
Zalosh, R.G., and T.P. Short, 1978. Compilation and Analysis of Hydrogen Accident Reports, FMRC J. I. 4A7NO.RG, RC78-T-54, Factory Mutual Research Corporation, October.

Zerga, D., 1980. Archaeological Reconnaissance of Three Proposed Geologic Trenches in the Yucca Mountain Area of the Nevada Test Site. Desert Research Institute Cultural Resources Reconnaissance Short Report No. SR082980-4-5-6.

Zupp, R.O., 1989. Preliminary Engine Integration Test Requirements, Grumman Space System, July 31.

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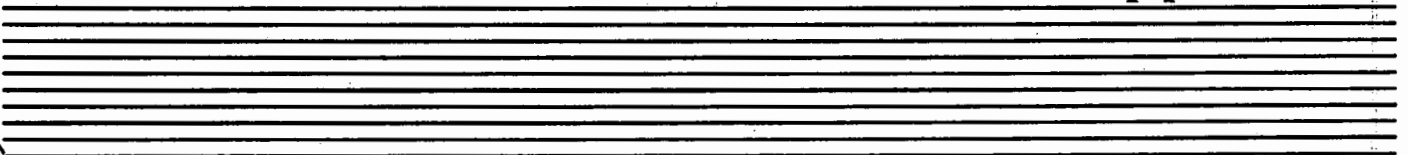
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Appendices



Appendix A



APPENDIX A

GLOSSARY OF TERMS AND ACRONYMS/ABBREVIATIONS

APPENDIX A

GLOSSARY OF TERMS AND ACRONYMS/ABBREVIATIONS

GLOSSARY OF TERMS

AIRDOS-EPA. A computational methodology for estimating environmental concentrations and dose to man from airborne releases of radionuclides.

Ambient Air Quality Standards. Standards established on a federal or state level which define the limits for airborne concentrations of designated criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, lead, ozone, and particulate matter [PM₁₀]).

As Low As Reasonably Achievable (ALARA). An approach to radiation protection to control or manage exposures (both individual and collective to the work force and general public) as low as social, technical, economic, practical, and public policy considerations permit. ALARA is not a dose limit but a process, which has the objective of dose levels as far below applicable limits as possible.

Atmospheric Dispersion. The process of air pollutants being dispersed in the atmosphere by the wind that carries the pollutants away from their source and by turbulent air motion that results from solar heating of the earth's surface and air movement over rough terrain and surfaces.

Attainment Area. An area that has been designated by the U.S. EPA and the appropriate state air quality agency as having ambient air quality (levels below the ceiling levels defined under the National Ambient Air Quality Standards (NAAQS)).

Background Radiation. Ionizing radiation present in the environment from cosmic rays and natural sources in the earth; background radiation varies considerably with location.

Baseline. The existing characterization of an area under no-project conditions.

Control Facility. The control facility is an earth covered reinforced-concrete building in which the PBR validation test activities would be controlled and monitored. Other projected activities performed from the control-facility include access control to the test station.

Coolant. A substance, either gas or water, circulated through a nuclear reactor or processing plant to remove heat.

Core Release Fractions. That fraction of the Fission Product Inventory released from the reactor core during either normal operation or during accidental release.

Core Release. The quantity of radionuclides released from the reactor core. The result of the Fission Product Inventory and the Core Release Fraction

Cosmic Rays. Electrons and the nuclei of atoms, largely hydrogen, that impinge upon the earth from all directions of space with nearly the speed of light. Also known as cosmic radiation; primary cosmic rays.

Council on Environmental Quality (CEQ). Established by the National Policy Act (NEPA), the CEQ consists of three members appointed by the President. CEQ regulations (40 CFR Parts 1500-1508, as of July 1, 1986) described the process for implementing NEPA, including preparation of environmental assessments and environmental impact statements, and the timing and extent of public participation.

Critical Assembly. An assembly of sufficient fissionable and moderator material to sustain fission chain reaction at a low power level.

Cryogenic Fluids. Those fluids that are below a temperature of 150 K. In the context of this EIS, cryogenic fluids include liquid hydrogen and liquid oxygen.

Cryogenic Hydrogen. Hydrogen at temperatures below 150 K, which has been transformed from a gas to a liquid. Cryogenic hydrogen may be used as both a coolant and propellant.

Cultural Resources. Any building, site, district, structure, object, data, or other material significant in history, architecture, archaeology, or culture.

Cumulative Effects. The aggregation of project included effects within the project's Region of Influence. The term cumulative has also been used to denote aggregated effects over several years as against net effects in a given year.

Decommissioning. The permanent removal from service of the surface facilities and components of the validation test facility.

Decontamination. The removal of unwanted material (especially radioactive material) from the surface of or from within other material.

Deflagration. Combustion in which the flame speed is below the speed of sound.

Detonation. Combustion in which the flame speed is above the speed of sound.

Dewar. A double walled glass or metal flask container that is well insulated with a vacuum in the annulus. It is used for storing liquified gases and hot or cold fluids. Large vessels are used for truck and rail movement of liquified gases.

Disturbed Area. Specific land area which has had its surface altered by grading, digging, or other activities related to construction.

Dose Commitment. Dose commitment is that total radiation dose equivalent, internal or external in origin, to the whole body or specified part of the body, that will be received during the 50-year period following the release of radioactive material to the specific environment. Dose quantities that apply to the "Whole Body" shall also apply to the head and trunk, active blood-forming organs, gonads, and lens of the eyes. Dose quantities that apply to "Other Organs" shall apply to those organs not specified above.

Dose Equivalent (H). The product of absorbed dose (d) in rads (or gray) in tissue, a quality factor (Q), and other modifying factors (N). Dose equivalent (H) is expressed in units of rem (or sievert).

Effluent. Waste material discharged into the environment. In the case of this EIS, the major effluent of concern is that produced by the testing of the ground test articles.

Effluent Treatment System (ETS). A system designed to remove fission contaminants generated as a result of some of the ground testing activities. The ETS would be designed to treat radioactive particulate, iodine, and noble gas releases.

Emission Factor. The rate at which a pollutant is emitted from a point, line, or area source.

Endangered Species. A species that is threatened with extinction throughout all or a significant portion of its range. Defined by the Endangered Species Act, as amended (16 USC 703 et seq.).

Engine Nozzle. The engine nozzle is the orifice through which the hot hydrogen propellant is ejected to initiate thrust.

Engine Integration Test (EIT). The Engine Integration Test is a test designed to demonstrate the propellant management system without an operating reactor in the loop. Heat would be generated by combusting hydrogen in an oxygen-rich environment.

Ephemeral. Lasting for a day or less.

Epicenter. The point on the earth's surface directly above the focus of an earthquake.

ETS Release Fractions. The fraction of radionuclides sent to the ETS that are released from the Effluent Treatment System.

Exposure rate (X). The exposure per unit time.

Fission Product Inventory. Those radionuclides created within the reactor core during operation as a direct result of the fission process.

Frit. A frit is a concentric metal cylinder that acts as a supporting structural member while being sufficiently porous to allow gas to flow through. In the PBR fuel element design, a "cold" frit is maintained at low temperatures and is used to control flow and pressure drop. A "hot" frit operates at high temperatures and forms a companion cylinder to the cold frit, confining and supporting the fuel particles.

Fuel Element. The smallest structurally discrete part of a reactor or fuel assembly that has nuclear fuel as its principal constituent. The term fuel element is a general term and a more precise term such as fuel pellet, plate, rod, pin, cluster, bundle or subassembly, or assembly should be used.

Fuel Kernels. Fuel kernels are the center of the fuel particles which contain the enriched uranium.

Fuel Particle. A fuel particle is a tiny microsphere that contains fissile material. It consists of either a kernel of highly enriched uranium carbide, concentric carbon layers of varying densities, and one or more refractory coatings.

Full-Scale Facility. The full-scale facility consists of the sub-scale facility expanded to accommodate the EIT, mini-GTA, and GTA testing activities. Additional upgrade from the sub-scale facility includes additional testing cells, coolant storage and control instrumentation.

Gigawatts. A unit of power equal to 1 billion watts.

Ground Test Article (GTA). The Ground Test Articles are a series of up to ten reactors which, as they are tested, gradually approach the desired prototypic conditions. The mini-GTAs are sub-scale test articles while the GTAs are full-scale test articles.

Halogens. Any of the elements that form part of group VII A of the periodic table and exist in the free state normally as diatomic molecules, these include fluorine, chlorine, bromine, iodine, and astatine.

Hot Hydrogen Gas Generator. This is a generator that generates hot hydrogen gas (approx 2700 K; 2430° C) by combusting hydrogen in an oxygen-rich environment. The hot-hydrogen gas generator is used as part of the Engine Integration Test.

Inversion. A reversal of a normal atmospheric temperature gradient, causing increasing temperatures with height.

Ionizing Radiation. Radiation that can displace electrons from atoms or molecules, thereby producing ions.

Irreversible & Irretrievable Commitment of Resources. Involves land areas committed during operation, funding for construction and materials, chemicals, and water that would be consumed during construction and operation and would be unable to replace.

Isotope. Isotopes of an element are atoms that contain the same number of positive nuclear charges and have the same extra-nuclear electronic structure, but differ in the number of neutrons.

Joule. A unit of energy of work equivalent to 1 Watt per second, 0.737 foot-pound, or 4.18 calories.

Kelvin (K). A temperature scale that designates absolute zero as 0 K(-273°C).

Land Disposal Restrictions (LDR). Hazardous wastes which are subject to restrictions for land disposal as identified and defined in 40 CFR Part 268.

Latent Cancer Fatality (LCF). A death from cancer which is attributed to exposure to ionizing radiation.

Low Level Wastes (LLW). All radioactive waste not classified as high-level waste, spent nuclear fuel, transuranic waste, uranium mill tailings or Mixed Waste. LLW can contain transuranic nuclides in concentrations not greater than 100 nanocuries per gram.

Maximum Exposed Individual (MEI). The location of maximum radiological impact (highest dose) in unrestricted access areas. This location represents the site of the maximum exposure which a person could receive if present throughout the exposure duration. This value is used for comparison with regulatory (NESHAP) requirements for airborne releases of radioactive material.

Megajoules. A unit of energy. Work performed when power is expended at the rate of 1 watt for 1 second. The work performed by 1 newton acting through a distance of 1 meter. Million joules.

Megawatts. A unit of power equal to 1 million watts.

Mesozoic. A period of geologic time extending from about 245 million to 66 million years ago.

millirem. A fractional unit of rem. 1 millirem = 1/1,000 rem.

Mini-GTA. The mini-GTA is the sub-scale test article tested prior to the Ground Test Article (GTA).

Mitigations. Methods to reduce or eliminate adverse project impacts.

Mixed Wastes. Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively.

National Environmental Policy Act (NEPA). Public Law 91-190, passed by Congress in 1969. The Act established a national policy designed to encourage consideration of the influences of human activities (e.g., population growth, high-density urbanization, industrial development) on the natural environment. NEPA also established the Council on Environmental Quality. NEPA procedures require that environmental information be made available to the public before decisions are made. Information contained in NEPA documents must focus on the relevant issues in order to facilitate the decision-making process.

National Priorities List (NPL). A list of sites (federal and state) that contain hazardous materials that may cause an unreasonable risk to the health and safety of individuals property, or the environment.

Nonattainment Area. An area that has been designated by the U.S. EPA and appropriate state air quality agency as exceeding one or more National Ambient Air Quality Standards.

Normal Operation. The range of full-power operation conditions that can be achieved when seasonal variations in ambient conditions are taken into account.

Nuclear Element Tests (NET). This is a series of tests designed to demonstrate the integrity and performance of fuel element designs under conditions of high temperature and moderate hydrogen flow.

Operational Boundary. The operations boundary is the reactor building (or the nearest physical personnel barrier in cases where the reactor building is not a principal physical personnel barrier) where the reactor chief administrator has direct authority over all activities. The area within this boundary shall have prearranged evacuation procedures known to personnel frequenting the area.

Orbital Transfer Vehicle (OTV). An OTV can be thought of as a reusable, space-based tugboat. Once deployed in low earth orbit (LEO), an OTV would be sent to retrieve/return a satellite in a higher orbit not accessible by the space shuttle or space station. Such a capability would allow LEO repair and servicing of expensive military satellites which are currently disposed of due to failure and/or depletion of on-board, station-keeping propellant. This leads to reduced launch costs, less space debris, and an improved amortization of military space-based assets. After use, the OTV would be reserviced by astronauts for a future retrieval mission. Because OTVs require a nearly permanent human presence in LEO, they have not been used. OTVs only become attractive with a robust space transportation system, including routine human access to space. OTVs would operate at thrust levels comparable to a launch vehicle third stage (10-50 thousand pounds).

ORIGEN. An acronym for ORNL Isotope Generation. ORIGEN-2 is the second generation of the code.

Particle Bed Reactor Integral Performance Element Test (PIPET). This is a series of tests designed to demonstrate the reactor fuel elements operation at prototypic power densities, temperatures, pressures, flow rates, and power durations.

Particle Bed Reactor (PBR). The Particle Bed Reactor is a nuclear reactor fueled by elements comprised of small microspheres placed in an annulus formed by a cold and hot frit. The reactor is cooled by cryogenic liquid hydrogen.

Pasquill Stability Class. Stability classes ranging from A (extremely unstable) through F (Moderately Stable) indicate the turbulent nature of the atmosphere. Extremely unstable conditions enhance diffusion (generally reducing pollutant concentrations) while moderately stable conditions inhibit diffusion and pollutant dispersion.

Plume. The elongated pattern of contaminated air or water originating at a point-source emission, such as a smokestack, or a waste source, such as a hazardous waste disposal site.

Population Center Distance. The distance from a power or testing reactor to the nearest boundary of densely populated center containing more than 25,000 residents (see 10 CFR 73.2).

Propulsion System. In the context of this EIS, the propulsion system is the PBR reactor engine.

Production Reactor. A reactor whose primary purpose is to produce fissile or other materials or to perform irradiations on an industrial scale. Unless otherwise specified, the term usually refers to a plutonium-production reactor. Reactors in this class include fissile material production reactor, isotope-production reactor, and irradiation reactor.

Protected Area. An area encompassed by physical barriers to which access is controlled (see 10 CFR 73.2).

Quaternary. A geologic period of the Cenozoic era extending from about 1.6 million years ago to the present.

Radioactive Waste. Materials from nuclear operations that are radioactive or are contaminated with radioactive materials, and for which use, reuse, or recovery are impractical.

Radioactivity. The spontaneous decay or disintegration of unstable atomic nuclei, accompanied by the emission of radiation.

Radioisotope. Nuclides of the same element (same number of protons in their nuclei) that differ in the number of neutrons and that spontaneously emit particles or electromagnetic radiation.

Reactor Control. Safety rods, control drums, or other mechanisms used to control the fission process within a reactor.

Region of Influence. The geographical region which would be expected to be affected in some way by the proposed action. Generally, a region of influence is defined for each resource area associated with a proposed action.

Rem. Unit of exposure to biological material calculated by multiplying the dose (in rads) by a quality factor which accounts for the biological effectiveness of the type of radiation producing the exposure.

Remote Inspection and Maintenance System. Inspection and maintenance of radioactive or contaminated equipment by means of a manipulator or robot.

Rural Zone. A rural zone is a sparsely populated but not directly controlled area or neighborhood where evacuation of all personnel can be achieved in less than 2 hours using available resources.

Sievert (Sv). A unit used to measure dose equivalent. The Sievert is the product of the absorbed dose (D in gray) in tissue, a quality factor (Q), and other modifying factors (N).
(1 Sv = 100 rem = 1 Joule/kilogram tissue).

Sintered. Process for heating alloys to a temperature less than the melting point.

Site Boundary. The site boundary is that boundary, not necessarily having restrictive barriers surrounding the operations boundary wherein the reactor administrator may directly initiate emergency activities. The area within the site boundary may be frequented by people unacquainted with reactor operation.

Site-Specific. Characteristic of a geographically defined location that may vary considerably from characteristics of adjacent locations or the characteristics of a larger area within which the location in questions is contained.

Solid Wastes. Waste material that is an essentially in a dry, solid form. Waste may include well-drained containers or liquids which have been entrapped or otherwise solidified so that they will retain their solid form without the presence of free liquids during handling, transportation, storage, or disposal. Viscous waste material is determined to be a solid by testing in accordance with American Society for Testing Materials Standards D4359, "Standard Test Method for Determining Whether a Material is a Liquid or a Solid."

Source Term (System Release). The quantity of radionuclides released from the test system to the environment during either operational or accidental conditions. The Source Term is the product of the Fission Product Inventory, the Core Release Fractions, and the ETS Release Fractions.

Special Nuclear Material. Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the NRC, pursuant to the provisions of section 51 of the Atomic Energy Act of 1954 determines to be special nuclear material.

Specific Impulse (Isp). Specific impulse is a measure of the effectiveness of rocket engine and is expressed in units of time (seconds); it represents the capability of generating a unit of force (pounds) for a given period of time (seconds) for a unit of propellant weight (pounds).

Sub-Scale Facility. The sub-scale facility is the first phase of the ground test activity that is intended to accommodate the PIPET testing. The sub-scale facility would include a control bunker, data acquisition and instrumentation/control systems, a receiving and assembly facility, a test cell, a coolant supply system, an effluent treatment system, a remote inspection and maintenance system, roads and services, and safeguards and physical security.

Supercritical Fluids Process. This is one of three processes used to create fuel kernels. This process involves the deposition of zirconium into a porous uranium-carbon kernel. Supercritical fluids are non-wetting dense gases and are obtained by controlling temperature and pressure in a controlled reaction chamber. They are used to carry the zirconium carbide precursors into the fine porosity of the kernel.

Thermoluminescent Dosimeters. These instruments measure ionizing radiation exposures from natural radioactivity in the air and soil, cosmic radiation from outer space, fallout from nuclear weapons tests, radioactivity from fossil fuel burning, and radioactive emissions from site operation and other industrial processing.

Threatened Species. A species that has the potential to become endangered. Defined by the Endangered Species Act, as amended (16 USC 703 et seq.).

Thrust-to-Weight Ratio. A measure of the performance of a rocket engine; it is the thrust produced by the engine divided by the weight of the engine and propellant.

Transuranic Waste (TRU). Radioactive waste containing alpha-emitting radionuclides having an atomic number greater than 92 and half-lives greater than 20 years in concentrations greater than 100 nci/g.

U-235. A fissionable isotope of uranium.

Upper Stage. An Upper Stage is the second or third stage of a space launch vehicle. Depending on the mission, it will ignite either in the upper reaches of the atmosphere or in LEO. On a two-stage launch vehicle, the Upper Stage delivers the payload to LEO while a three-stage vehicle uses the Upper Stage to deliver the payload to geosynchronous orbit (GEO) or an earth escape trajectory. Typically, Upper Stages operate between 10 and 100 thousand pounds of thrust, depending on launch vehicle and stage. Current chemical propellant Upper Stages are expended after use.

Urban Boundary. The urban boundary means the nearest boundary of a densely populated area or neighborhood containing population of such number or in such a location that a complete rapid evacuation is difficult or cannot be accomplished within 2 hours using available resources.

Wetlands. Areas defined by the prevailing vegetation types and soil moisture content and consisting of vegetation types and soil moisture content and consisting of vegetation typical of soils that are saturated for a major portion of the year.

ACRONYMS AND ABBREVIATIONS

AADT	average annual daily traffic
AFR	Air Force regulation
ALARA	as low as reasonably achievable
ANL-W	Argonne National Laboratory West
ANS	American Nuclear Society
ANSI	American National Standards Institute
APE	area of potential effect
ARCHIE	Automated Resource for Chemical Hazard Incident Evaluation
ASME	American Society of Mechanical Engineers
B&W	Babcock and Wilcox
BLM	Bureau of Land Management
BP	before present
BWMF	Bulk Waste Management Facility
C	centigrade
CAA	Clean Air Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CP-1	Control Point 1
CSS	coolant supply system
CTF	Contained Test Facility
dBA	adjusted decibel
DEIS	draft environmental impact statement
DOD	Department of Defense
DOE	Department of Energy
DOE/NV	Department of Energy Nevada Field Office
DOT	Department of Transportation
DRI	Desert Research Institute
DSB	Defense Science Board
E-MAD	engine maintenance and disassembly
EIS	environmental impact statement
EIT	engine integration test
EM	Environmental Restoration and Waste Management
EOC	Environmental Operations Center
EPA	Environmental Protection Agency
ETS	effluent treatment system
FEIS	final environmental impact statement
FRMAC	Federal Radiological Measurement and Assessment Center
GH ₄	gaseous helium
GH ₂	gaseous hydrogen
GTA	ground test article
HEPA	high efficiency particulate air
INEL	Idaho National Engineering Laboratory
Isp	specific impulse
K	Kelvin
kPa	kilopascals
kV	kilovolt
LCF	latent cancer fatality

LDR	land disposal restrictions
LH ₂	liquid hydrogen
LLW	low level wastes
LN ₂	liquid nitrogen
LOX	liquid oxygen
MACCS	MELCOR Accident Consequence Code System
MEI	Maximum Exposed Individual
mg/l	milligrams per liter
MGD	million gallons per day
MPa	megapascals
mrem	milliroentgen equivalent man (millirem)
mrem/yr	millirems per year
MSL	mean sea level
MVA	megavolt amperes
MW	megawatts
MWMU	mixed waste management unit
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NRDA	Nevada Research and Development Area
NTS	Nevada Test Site
OSHA	Occupational Safety and Health Administration
PBR	particle bed reactor
PIC	pressurized ion chamber
PIPET	particle bed reactor integral performance element test
PM ₁₀	particulate matter less than 10 microns in diameter
PSD	prevention of significant deterioration
psi	pounds per square inch
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RWMC	Radioactive Waste Management Complex
RWMS	Radioactive Waste Management Site
SAR	safety analysis report
SER	safety evaluation report
SARA	Superfund Amendment and Reauthorization Act
SHPO	State Historic Preservation Officer
SMTS	Saddle Mountain Test Station
SNL	Sandia National Laboratories
SNTP	Space Nuclear Thermal Propulsion
SRS	Savannah River Site
SST	safe, secure transport
SSW	south-southwest
SW	southwest
TAN	Test Area North
TRU	transuranic
UBC	Uniform Building Code



USC
WIPP
WROC
WSNSO

U.S. Code
Waste Isolation Pilot Plant
Waste Reductions Operations Complex
Weather Service Nuclear Support Office

ABBREVIATIONS OF ELEMENTS/CHEMICALS

Ac	Actinium
Ag	Silver
Al	Aluminum
Am	Americium
As	Arsenic
Ba	Barium
Be	Beryllium
Br	Bromine
C	Carbon
Cd	Cadmium
Ce	Cerium
Cf	Californium
Co	Cobalt
CO	Carbon monoxide
Cs	Cesium
Cu	Copper
Dy	Dysprosium
Er	Erbium
Eu	Europium
Ga	Gallium
Gd	Gadolinium
Ge	Germanium
H	Hydrogen
Ho	Holmium
I	Iodine
In	Indium
Kr	Krypton
La	Lanthanum
Mg	Magnesium
Mo	Molybdenum
Na	Sodium
Nb	Niobium
Nd	Neodymium
NO _x	Nitrogen oxides
NO ₂	Nitrogen dioxide
Np	Neptunium
O ₂	Oxygen
O ₃	Ozone
Pa	Protactinium
Pb	Lead
Pd	Palladium
Pm	Promethium
Po	Polonium
Pr	Praseodymium
Pu	Plutonium
Rb	Rubidium
Rh	Rhodium
Ru	Ruthenium
Sb	Antimony

Se
Si
Sm
Sn
SO₂
Sr
Tb
Tc
TCE
Te
Th
U
Xe
Y
Zn
Zr

Selenium
Silicon
Samarium
Tin
Sulfur dioxide
Strontium
Terbium
Technetium
Trichloroethylene
Tellurium
Thorium
Uranium
Xenon
Yttrium
Zinc
Zirconium

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APPENDIX B
NOTICE OF INTENT

**NOTICE OF INTENT
TO PREPARE AN ENVIRONMENTAL IMPACT STATEMENT
SPACE NUCLEAR THERMAL PROPULSION PROGRAM**

The Department of the Air Force is conducting the Space Nuclear Thermal Propulsion (SNTP) Program to develop the technology for a nuclear thermal propulsion system. The SNTP Program Office at Phillips Laboratory, Kirtland AFB, NM is managing program activities and intends to study the environmental issues associated with the SNTP program. To this end, the Air Force Center of Environmental Excellence (AFCEE) will prepare an Environmental Impact Statement (EIS) for use in the decision-making process.

Successful development of nuclear thermal propulsion system technology would allow future consideration of the acquisition of a cost-effective rocket to support national defense and civil space missions.

SNTP Program decisions to be made include: a) whether or not to continue the SNTP program through the development of nuclear thermal propulsion technology; b) whether or not to construct and operate a ground test facility; and c) where to locate the ground test facility if the program is to continue. Decisions on whether to build a rocket for flight testing and the acquisition of operational rockets are not included in the proposed action; these decisions are not part of the SNTP technology development program.

The SNTP ground test facility is proposed to be located at either the Nevada Test Site or the Idaho National Engineering Laboratory.

Scoping will be conducted to identify environmental concerns and issues that need to be addressed in the EIS. The EIS will assess the issues pertaining to the decisions to be made. Two public scoping meetings will be held as part of the process (one each in Las Vegas, NV and Idaho Falls, ID) to determine the environmental issues and concerns that should be addressed. The scoping meetings are tentatively scheduled for April 1992. Notice of the exact time and place of the meeting will be published in the news media.

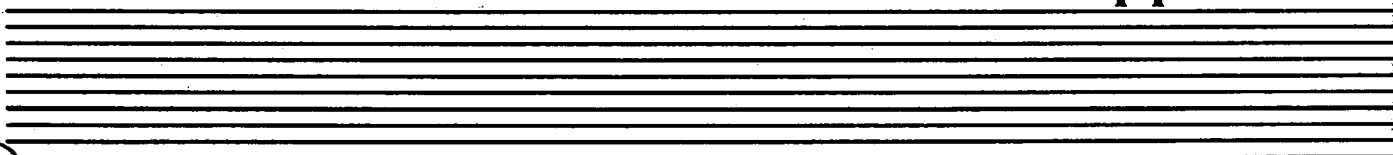
Public input and comments are solicited concerning the environmental aspects of the proposed program. To assure the program office will have sufficient time to fully consider public inputs on issues, written comments should be mailed to ensure receipt no later than May 15, 1992.

Comments concerning the proposed project or the EIS should be addressed to:

Lt Col Gary Baumgartel
Director of Environmental Planning
AFCEE/ESE
Building 1155
Brooks AFB, TX 78235-5000
(512) 536-3907

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Appendix C



APPENDIX C

DRAFT ENVIRONMENTAL IMPACT STATEMENT MAILING LIST

DRAFT ENVIRONMENTAL IMPACT STATEMENT MAILING LIST

Federal Agencies - National

Advisory Council on Historic Preservation
Attn: Don Klima, Director
Office of Project Review
1100 Pennsylvania Avenue, NW, #809
Washington, DC 20004

AFCEE/ES-S
Regional Compliance Office
Attn: Phil Lammi
630 Sansome Street, Room 1316
San Francisco, CA 94111

Brookhaven National Laboratory
Attn: Mr. Walter Kato
Building 197c
29 Cornell Drive
Upton, NY 11973

Center for Environmental Health and
Injury Control (P29)
Special Programs Group
Centers for Disease Control
Atlanta, GA 30333

Department of Agriculture
Environmental Coordination Office
Attn: Robert Cunningham
Forest Service - USDA
P.O. Box 96090, Room 4204
Washington, DC 20090

Department of Commerce
Attn: Ms. Allison Kaufman
Director, Office of Intergovernmental Affairs
Room 5415, Commerce Building
Washington, DC 20230

Federal Aviation Administration
Attn: Louise Maillet, Director
Office of Environment and Energy
800 Independence Avenue, SW
Washington, DC 20591

Headquarters Environmental Protection
Agency
Office of Federal Activities (Mail Stop A-104)
Attn: Bearl Young
401 "M" Street, SW Room M-2119
Washington, DC 20460

J-DO, MS-F670
Attn: Dr. Mike Hynes
Los Alamos National Laboratory
Los Alamos, NM 87545

National Aeronautics and Space
Administration
Attn: John S. Clark
Lewis Research Center
Mail Stop AAC-2
2100 Brookpark Road
Cleveland, OH 44135

National Aeronautics and Space
Administration
Attn: Bonnie Kaltenstein
Lewis Research Center
Mail Stop AAC-2
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Cleveland, OH 44135

Department of Energy
Director, Environmental Compliance Division
Attn: Gus Vazquez
EH-232, Forrestal Building
1000 Independence Avenue, SW,
Room 3G-092
Washington, DC 20585-0001

Department of Energy/NE-50
Attn: Mr. E. Wholquist
19901 Germantown Rd.
Germantown, MD 20874

Department of Energy/EH-252
Attn: Mr. Robert Strickler
1000 Independence Ave., SW
Washington, DC 20585

Department of Energy/NS-20
Attn: Mr. Andrew Marchese
19901 Germantown Road
Germantown, MD 20874

Department of Energy/DP-9
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1000 Independence Ave., SW
Washington, DC 20585

Department of Energy/NE-52
Attn: J. Warren
19901 Germantown Rd.
Germantown, MD 20874

Department of Energy/GC-11/GA-113/FORS
Attn: Steve Ferguson
1000 Independence Ave., SW
Washington, DC 20585

Department of Energy/SC-1/GA-155/FORS
Attn: Roger Pressentin
1000 Independence Ave., SW
Washington, DC 20585

Department of Energy
Attn: Major Jim Felty
DP/241 GTN
Washington, DC 20585

Department of the Interior
Director, Office of Environmental Affairs
Main Interior Building, MS 2340
1849 "C" Street, NW
Washington, DC 20240

HQ USAF/CEVP
Attn: Mr. John Babicz
The Pentagon, Room 5D381
Washington, DC 20330-5130

Det 1, AFSA/SE
Attn: Col. Matson
Kirtland AFB, NM 87117

Los Alamos
National Laboratory
Attn: Susan Voss
SM30 Bikini Rd.
Los Alamos, NM 87545

Phillips Laboratory
Attn: Major Dave Kristensen,
Environmental Coordinator PL/VT-X
Kirtland AFB, NM 87117-6008

Sandia National Laboratories
Organization 6513, Building 962 Room 2402
Attn: Mr. George Allen
Albuquerque, NM 87185

Charles D. Harmon
400 15th Street, South #201
Arlington, VA 22202

William H. McCulloch
Innovative Technology Applications
Department 6514
Sandia National Laboratories
Albuquerque, NM 87185

Space Systems Division/CEV
Attn: John Edwards
2400 El Segundo Blvd.
Bldg. 130 Rm 1190
Los Angeles AFB, CA 90019-2960

USAFWTC/JAV
Attn: Jay McCain
17 England Ave.
Nellis AFB, NV 89191

Mr. Paul Klock
30 SPW/XPR
Vandenberg AFB, CA 93437-5000

IDAHO NATIONAL ENGINEERING
LABORATORY

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United States Senate
Washington, DC 20510-0001

Honorable Steve Symms
United States Senate
Washington, DC 20510-0001

Honorable Larry LaRocco
House of Representatives
Washington, DC 20515-0001

Honorable Richard Stallings
House of Representatives
Washington, DC 20515-0001

Federal Agency Regional Offices

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Director, Western Office of Project Review
730 Simms Street, Room 401
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Bureau of Indian Affairs
Western Nevada Agency
5533 Mark Twain Ave.
Carson City, NV 89701

Bureau of Land Management
Attn: David Brunner
3948 Development Avenue
Boise, ID 83709

Jim Werner
DOE Idaho Field Office
785 DOE Place, Mail Stop 1146
Idaho Falls, ID 83401-1562

Environmental Protection Agency, Region X
Attn: Jerry Opatz
Chief, Environmental Review Section
1200 6th Avenue, MS/WD126
Seattle, WA 98101

U.S. Fish and Wildlife Service
Regional Office
500 NE Multnomah Street
Portland, OR 97232

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P.O. Box 50130
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Box 367
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126 South 15th
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Honorable Mark G. Ricks
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Department of Health and Welfare
Attn: Steve Hill
INEL Oversight Program
1410 N. Hilton
Boise, ID 83706

Department of Lands
Attn: Stan Hamilton, Director
1215 W. State Street
Boise, ID 83720

Idaho Department of Agriculture
Attn: Dr. Bob Hillman
Box 7249
Boise, ID 83707

Idaho Department of Employment
Attn: Connie Ryals
317 Main
Boise, ID 83735

Idaho Department of Health and Welfare
Attn: James S. Johnston
IFFO Manager
INEL Oversight Program
1920 E. 17th St., Suite 202
Idaho Falls, ID 83404-8036

Idaho Department of Resources
Attn: Frank Sherman
State House Mail
Boise, ID 83720

Idaho Department of Water Resources
Attn: Dave Tuthill, Manager
Western Region Office
2735 Airport Way
Boise, ID 83705

Idaho Fish and Game Department
Attn: Cal Groen
Box 25
Boise, ID 83702

Idaho State Historical Society
Attn: David Crowder
State Historic Preservation Officer
210 Main Street
Boise, ID 83702

Idaho Transportation Department
Attn: Ted Gwin
8150 Chinden Blvd.
Boise, ID 83714

State Board of Education
Attn: Bill Hargrove
650 State Street
Boise, ID 83720

State Department of Education
Attn: Bob Dutton
Len B. Jordan Bldg.
Boise, ID 83720

State Public Affairs
Attn: Georgia Smith
700 W. State Street
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4329 North, 26 West
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SE Idaho Council of Governments
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342 Monroe Place
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Ammon, ID 83406

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Arco, ID 83213

Chubbuck City Council
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Chubbuck, ID 83202

Firth City Council
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Firth, ID 83236

Idaho Falls City Council
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Idaho Falls, ID 83405

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Inkom, ID 83245

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Mackay, ID 83251

Rigby City Council
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Rigby, ID 83442

Ririe City Council
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Ririe, ID 83443

Saint Anthony City Council
110 West Main Street
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Shelley City Council
101 South Emerson Avenue
Shelley, ID 83274

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Shoshone, ID 83352

Warm River City Council
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Native American Groups

Lindsey W. Manning
Tribal Planner
Shoshone-Paiute Tribes
Tribal Headquarters
P.O. Box 219
Owyhee, NV 89832

James Paiva
Chairman, Shoshone-Payette Tribes
P.O. Box 219
Owyhee, NV 89832

Herman Atkins
Traveling Chair
Shoshone-Paiute Tribes
P.O. Box 219
Owyhee, NV 89832

Tribal Chairman
Fort Hall Business Council
PO Box 306
Fort Hall, ID 83202

Public Interest Groups

Idaho Audubon Council
Attn: Al Larson
3015 Silver Street
Boise, ID 83703

Idaho Conservation League
Attn: Glenn Stewart, Executive Director
P.O. Box 844
Boise, ID 83701

INEL Committee - Idaho
Attn: Mr. Ross Farmer, Chairman
P.O. Box 50498
Idaho Falls, ID 83406

Middle Snake Group, Sierra Club
Attn: Joanie Fauci
2005 N. 10th St
Boise, ID 83702

Nature Conservancy
Attn: Guy Bonniver
P.O. Box 64
Sun Valley, ID 83353

Snake River Alliance
Attn: Mr. Blan Holman
310 East Center
Pocatello, ID, 83201

The Wilderness Society
Attn: Jane Leeson
413 W. Idaho Street, Suite 102
Boise, ID 83701

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Idaho Falls Public Library
457 Broadway
Idaho Falls, ID 83402

INEL Technical Library
1776 Science Center Drive
Idaho Falls, ID 83415

Pocatello Public Library
812 E. Clark
Pocatello, ID 83201

Twin Falls Public Library
434 2nd Street East
Twin Falls, ID 83301

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258 Idaho Street
P.O. Box 207
American Falls, ID 83211

Blackfoot Chamber of Commerce
P.O. Box 801
Blackfoot, ID 83221

Mackay Chamber of Commerce
P.O. Box 266
Oakley ID 83346

Rexburg Chamber of Commerce
134 East Main, #1
Rexburg, ID 83440

Shelley Chamber of Commerce
P.O. Box 301
Shelley, ID 83274

Shoneshona Chamber of Commerce
P.O. Box 575
Shoneshona, ID 83352

South Fremont Chamber of Commerce
110 West Main Street
Saint Anthony, ID 83445

NEVADA TEST SITE

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Honorable Barbara Vucanovich
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Washington, DC 20515-0001

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Honorable Orrin Hatch
United States Senate
Washington, DC 20510-0001

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House of Representatives
2421 Rayburn
Washington, DC 20515-0001

Honorable Bill Orton
House of Representatives
1723 Longworth Building
Washington, DC 20515-0001

Honorable Wayne Owens
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Environmental Protection Agency, Region IX
75 Hawthorne Street
San Francisco, CA 94105

Major General Thomas R. Griffith
Commander, TFWC
Nellis Air Force Base
Las Vegas, NV 89191-5000

John Leppert
DOE Building
2753 South Highland Drive
Las Vegas, NV 89109

Major General Billy G. McCoy, USAF
Commander, TFWC
Nellis Air Force Base
Las Vegas, NV 89191-5000

U.S. Fish and Wildlife Service
Regional Office
500 NE Multnomah Street
Portland OR 97232

J. Mark Fair
Weather Service Nuclear Support Office
Department of Commerce
2753 South Highland
Las Vegas, NV 89114

Water Resources Division
Department of Interior
833 Nevada Highway
Boulder City, NV 89005

State Elected Officials - Utah

Honorable Norman H. Bangerter
Governor of Utah
210 State Capitol
Salt Lake City, UT 84114

State Agencies - Utah

Utah State Clearinghouse
Attn: Ms. Carolyn Wright
Office of Planning and Budget
Room 116, State Capitol
Salt Lake City, UT 84114

Local Elected Officials - Utah

Honorable Karl Brooks
Mayor, City of St. George
175 East, 200 North
St. George, UT 84770

Local Government - Utah

Washington County Commission
Attn: Gayle M. Aldred
197 East Tabern
St. George, UT 84770

Washington County Commission
Attn: Scott Hirschi
197 East Tabern
St. George, UT 84770

Washington County
Commission
Attn: Jerry B. Lewis
197 East Tabern
St. George, UT 84770

State Elected Officials - Nevada

Honorable Bob Miller
Governor of Nevada
Capitol Building
Carson City, NV 89710

Frankie Sue Del Papa, Attorney General
State of Nevada
Heroes' Memorial Building
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Honorable Virgil M. Getto
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1400 Lovelock Highway
Fallon, NV 89406

Honorable Ray Rawson
Nevada Senate
6433 Meacham Avenue
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Honorable Matthew Callister
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823 Las Vegas Boulevard, South
Las Vegas, NV 89101

Honorable Gaylyn J. Spriggs
Nevada Assembly
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Hawthorne, NV 89415

State Agencies - Nevada

Department of Administration
State Clearinghouse
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Capitol Complex
Carson, City, NV 89710

Department of Agriculture
4009 W. Starfire Lane
Las Vegas, NV 89107

Department of Commerce
1850 E. Sahara Avenue
Las Vegas, NV 89158

Department of Conservation and
Natural Resources
Division of Historic Preservation and
Archaeology
128 West Nye Lane, Room 208
Capitol Complex
Carson City, NV 89710

Department of Conservation and
Natural Resources
Division of Forestry
Attn: Robert E. Poling, II
4747 W. Vegas Dr
Las Vegas, NV 89158

Department of Conservation and
Natural Resources
Division of Water Resources
Attn: G.W. Quinn, Chief Engineer
1515 E. Tropicana Ave, Suite 375
Las Vegas, NV 89119

Division of Emergency Management
Attn: Susan C. Moore
2525 S. Carson Street
Capitol Complex
Carson City, NV 89710

Las Vegas Environmental Monitoring &
Systems Lab
Attn: Robert Snelling
944 East Harmon Avenue
P.O. Box 93478
Las Vegas, NV 89193

Nevada Department of Commerce
Attn: Larry D. Struve, Director
Nye Building Room 321
1665 Hot Springs Rd
Carson City, NV 89710

Nevada Division of Planning
Blasdel Building Room 20
Capitol Complex
Carson City, NV 89710

Nevada State Division of
Environmental Protection
Attn: L.H. Dodgion, Administrator
210 S. Fall Street
Capitol Complex
Carson City, NV 89710

Nevada State Geologist
Nevada Bureau of Mines & Geology
University of Nevada, Reno
Reno, NV 89557-0088

Nevada Wildlife Federation
Attn: Ken Struthers
6062 Big Bend
Las Vegas, NV 89115

Radiological Health Section
Bureau of Regulatory Health Services
Attn: Stan Marshall •
505 E. King Street
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Water Resources Division
Department of Interior
833 Nevada Highway
Boulder City, NV 89005

Weather Service Nuclear Support Office
Department of Commerce
2753 South Highland
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Honorable James Seastrand
Mayor, City of North Las Vegas
P.O. Box 4086
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Local Government - Nevada

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P.O. Box 336
Beatty, NV 89003

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Appendix D



APPENDIX D

SAFETY ANALYSIS REPORT OUTLINE

APPENDIX D SAFETY ANALYSIS REPORT OUTLINE

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Chapter 10 does not apply, and is intentionally omitted from this outline.

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APPENDIX E

**METHODS FOR CALCULATING RADIOLOGICAL AND
NONRADIOLOGICAL IMPACTS**

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APPENDIX E

METHODS FOR CALCULATING RADIOLOGICAL AND NONRADIOLOGICAL IMPACTS

1.0 DEVELOPMENT OF FACILITY RADIOLOGICAL RELEASE ANALYTICAL METHODOLOGY

In order to assess the potential impacts of radiological releases from the evaluation of PBR propulsion technology radiological operations (reactor tests and transportation of radioactive materials), studies were undertaken using computer modeling techniques to determine the radiation dosages received by the entire population from release of radioactive materials, as well as the dose to the maximally exposed individual due to reactor operations. Bounding case assessments (i.e., maximum credible impacts) were made both for routine operations and maximum credible accident scenarios.

1.1 MODEL SELECTION

Proper selection of a computer modeling code to analyze radiological impacts is critical to the accuracy of the analysis. In recent years, improved understanding of atmospheric transportation and diffusion of contaminants has been incorporated into codes of increasing complexity, which have been developed using lessons learned from previous codes and from field studies. Several codes were evaluated to determine the best candidate for PBR propulsion technology program radiological release modeling. These include AIRDOS-PC, CAP-88, RSAC-4, and MELCOR Accident Consequence Code System (MACCS). Each of these codes is capable of evaluating the dose consequences to both the maximally exposed individual and the total dose received by the entire exposed population (population dose), which are the two primary impacts of interest.

Several factors were evaluated in selection of the best code for PBR propulsion technology program modeling. First is the ability of the code to address short-term releases. Operation of both PIPET and GTA will occur for relatively short periods of time (<1,000 seconds). Since this release time cannot be considered either instantaneous (a "puff") or continuous (a "plume"), an evaluation was conducted which indicated that use of a model modified to account for a short, but significant, release time yields the most conservative output results. Second, the code must have the ability to handle a large number of isotopes. Since the number of radioisotopes which would be created during PIPET and GTA operations is quite large, the greater the number of isotopes a code can handle, the more closely modeling results will reflect actual impacts. Third, the code must be able to address each of several identified exposure routes (cloudshine, groundshine, inhalation, resuspension of deposited material, and ingestion of material

deposited in the food chain [water, crops, game animals, etc.]) in determining the total dosage imparted. Finally, consideration was given to the U.S. EPA requirement that AIRDOS-PC or CAP-88 be used to assess compliance with applicable NESHAP and other air emission standards unless approval for use of another code can be obtained¹.

After evaluation of the capabilities of each of the codes, MACCS was selected as providing the most conservative analysis of the dose consequences from PBR test program radiological releases. MACCS was developed by SNL as an accident risk assessment code for the USNRC. MACCS was chosen primarily for its ability to handle a short-term release of radioactive materials with user selected meteorological conditions more conservatively than the models AIRDOS-PC and CAP-88.

MACCS was selected over RSAC-4, primarily because ingestion dosage can be treated in a more conservative fashion, thus yielding generally higher (i.e., more conservative) results. In comparisons of results from past studies performed using both MACCS and RSAC-4, MACCS was demonstrated to yield results which were somewhat higher than those obtained with RSAC-4, thus MACCS can be considered to be the more conservative code of the two.

While both AIRDOS-PC and CAP-88 were rejected for this analysis, for comparison purposes a preliminary assessment was performed using parameters for a normal GTA run using both MACCS and AIRDOS-PC. The dose results from AIRDOS-PC were less than those for MACCS by approximately a factor of fifty, primarily due to the inability of AIRDOS-PC to properly handle short-term releases, and the limited number of isotopes which can be analyzed. Thus MACCS can be demonstrated to be the most conservative of the models investigated. However, without EPA approval for MACCS usage, either AIRDOS-PC or CAP-88 will be used to present compliance with NESHAP.

1.2 SELECTION OF METEOROLOGICAL CONDITIONS

Unlike radiological dispersion calculations performed for continuously emitting facilities, the PBR propulsion technology evaluation facilities may be more accurately analyzed using short-time release scenarios. Typical PBR propulsion technology evaluation operations would be much less than an hour in duration, and flow times necessary for cooling are on the order of

¹ EPA provides guidance requiring on- and off-site dispersion and consequence modeling in 40 CFR Part 61, Subpart H, EPA Regulations on NESHAP. That guidance is incorporated in DOE Order 5400.5, Radiation Protection of the Public and the Environment for modeling off-site doses to the public. DOE Order 5400.5 states: "Analytical models used for dose evaluations shall be appropriate for characteristics of emissions ... mode of release (e.g., stack or vent; crib or pond; surface water or sewer; continuous or intermittent)." In addition, the order states: "Dose evaluation models that are codified, approved, or accepted by regulatory and other authorities shall be used where appropriate, such as the AIRDOS/RADRSK codes for demonstrating compliance with 40 CFR Part 61, Subpart H." Use of other models is dependent upon EPA approval, which is generally granted only if it can be demonstrated that the desired model is more conservative or accurate than the approved models (AIRDOS-PC and CAP-88).

several hours. During such short-term operations, much would be known about the volume of radiological material and the existing atmospheric weather conditions into which the operational or accident releases could be deposited. This allows analysis to be performed using conservative data that represent the allowable conditions at which maximum impacts will occur, rather than typical weather sampling analysis used for continuously emitting sources where weather conditions can and do change significantly over the course of a year's operation.

Considerable amounts of historical weather data are available for both INEL and, more especially, NTS. These are provided by extensive weather monitoring and forecasting networks established at each site. Forecasting of test-time weather conditions would be undertaken starting several days prior to a planned operation. These forecasts would be updated continuously right up to start of testing, and could be expected to be accurate for a period of 10 to 12 hours post-test based upon historical weather data. This procedure is already practiced at NTS, where forecasting is performed in advance of underground testing of nuclear weapons. This pre-test forecasting of weather ensures that predictable conditions will exist for the expected duration of test operations, and allows the selection of bounding case weather conditions that will produce the maximum impact allowed for test operations to proceed.

Two sets of bounding case weather conditions were developed for the consequence analysis: model operating weather and potential accident-case weather. Normal operating weather conditions (hereafter denoted as model conditions) represent a maximum-case combination of weather parameters at which a test operation will be permitted to begin. This go/no-go decision is based upon real-time analysis of potential accident impacts, which cannot exceed facility-established criteria of 170 mrem in any uncontrolled area. Bounding accident-case weather conditions, were selected to represent the significantly deteriorated weather conditions, relative to the model conditions which may be encountered beyond the ten to twelve hour pre-test forecast window.

Four parameters are used to describe weather conditions at each site: wind speed, plume direction, height of the inversion layer base, and atmospheric stability. The presence of an inversion layer represents a ceiling above which released contaminants cannot rise. This reduces the time required for a release to impact at ground level, and limits the available volume in which contaminants can disperse. Atmospheric stability is the rapidity with which a release will mix and disperse in the air, and is represented by Pasquill stability conditions. These are expressed as conditions ranging from Stability A through Stability F. Stability A represents an extremely turbulent, rapidly mixing atmosphere (minimizing the downwind concentration), while Stability F represents an extremely calm, slowly mixing

atmosphere (maximizing the downwind concentration). Stabilities B through E represent the range of conditions in between. Table E-1 provides a summary of the selected model weather conditions, while Table E-2 provides a summary of the accident-case conditions.

Table E-1. Model Weather Conditions

	NTS	INEL
Pasquill Stability Class	D	D
Wind Speed (m/s)	5.5	5.5
Plume Direction	NNE ¹	NNE ¹
Inversion Base Height (m)	2,000	1,500

¹Generally in the northerly direction

Table E-2 Bounding Accident-Case Weather Conditions

	NTS	INEL
Pasquill Stability Category	F	F
Wind Speed (m/s)	1.0	1.0
Plume Direction	Highest Population	Highest Population
Inversion Base Height (m)	300	300

Model wind speed, direction, and stability data were selected at the NTS based on the results of the nearest National Oceanic and Atmospheric Administration (NOAA) operated monitoring station (MEDA-14) to the SMTS. Pasquill stability D (neutral stability) was selected even though classes B and C occur more frequently, since class D will result in a more conservative estimate of the impacts. Stability classes E and F occur less frequently at SMTS than do classes A through D; when they exist, they are typically present in the early morning hours only. The average wind speed at SMTS is 5.5 meters per second (m/s) and was selected as the model wind speed for which analyses at SMTS are evaluated. The selected model (and measured average) wind direction at SMTS is north-northeast (NNE).

The model inversion layer chosen at NTS was based on a yearly averaged number. Inversions at NTS occur approximately 40 percent of the time in the spring, 20 percent in the summer, 50 percent in the fall, and 65 percent of the time in the winter (Quiring, 1973). Inversion layer statistics list a yearly averaged inversion layer base altitude of approximately 2.5 kilometers (the yearly average is computed from the average spring, summer, fall, and

winter values). For conservatism 80 percent of this altitude, or 2.0 kilometers, was selected as the model mixing layer altitude.

Model weather data at the INEL site were taken from weather data obtained by NOAA at INEL (Clawson, 1989). Model stability classes at INEL are similar to NTS, with E and F stability being somewhat more common year-round. However, like NTS, the E and F stabilities are primarily restricted to the early morning hours when they exist. Average wind speeds at ground level at INEL are somewhat slower than at NTS, averaging 3.2 m/s. However measurements at 150 and 250 feet, approximately the height of the ETS effluent stack, are similar to NTS at 5.6 m/s. Wind directions at INEL are more unpredictable than at NTS but at the 150 to 250 foot level are predominantly in a northeasterly direction. For these reasons a similar stability class D, wind speed 5.5 m/s, and wind direction, NNE, was selected at INEL.

At INEL inversions occur regularly and in general have lower base altitudes than found at NTS. Inversion statistics at INEL show a yearly average afternoon inversion base of 1.88 kilometers (calculated from seasonal average inversion data). As was determined for the NTS inversion layer, 80 percent of this height, or 1.5 kilometers, is taken as the model inversion layer height.

These weather conditions are based on available data at the sites of interest and represent conservative bounds on weather. It is important to understand that the weather conditions specified are not individual bounds that must be realized before operation can commence. The impacts which may occur as a result of a release would depend upon a combination of all weather-related factors (wind speed, wind direction, atmospheric stability, inversion layer height). Thus, many different combinations of these factors can yield a similar set of resulting impacts. Precise combinations of meteorological conditions that have been selected for use in the analysis are meant to represent one set of conditions that will result in the bounding case impacts. Each individual weather parameter should not be viewed as the minimum/maximum acceptable for operations to commence, but rather as part of a combination of parameters that will determine acceptability for testing. During actual operational testing, real time weather assessments and impact modeling, very similar to those performed before an underground test at NTS, would be performed to determine if accident releases may produce impacts which exceed acceptable criteria, thus initiating a test hold.

Plume rise was also considered in modeling of release impacts. The higher a release is able to rise (limited by inversion if present), the greater the degree of dispersal and mixing (i.e., lowering the concentrations) prior to ground-level contact where people may directly encounter the material. The height to which a release is able to ascend is based upon such factors as temperature and heat content of the release cloud, and release height.

(effluent stack as opposed to ground level). For operational releases, the release point would be through the ETS flare stack (for burning of hydrogen).

Plume powers necessary to specify buoyant rise are defined by the energy release from burning hydrogen and the hydrogen flow rate for normal operations. The hydrogen flow rate out the flare stack for typical operations is estimated as 134 kilograms per second (kg/s) for PIPET operations, and 536 kg/s for GTA operations. The energy release from burning 1 kg of hydrogen is given as 121 megajoules per kilogram (MJ/kg) (NASA, 1968). This results in a plume power of 16.2 gigawatts (GW) (1 GW equals 1 billion watts) for PIPET and 64.9 GW for GTA. A recent investigation shows that for hydrogen flow rates of 10 to 20 kg/s, one can expect plume rise in excess of 2 kilometers (Carney, 1992), which is in excess of inversion base heights used in this assessment. Since the inversion base is considered to be the maximum possible rise height in this analysis, inversion height is accepted as the final rise height for all assessments of PBR propulsion technology bounding case scenarios. Consideration of plume rise also allows evaluation of a hydrogen fire concurrent with an accidental release. However, for all such cases the accidental lofting produced by the hydrogen is negated by the inversion layer boundary.

1.3 RADIOLOGICAL RELEASES

Radiological consequence assessment is based upon the quantities of various radionuclides which escape to the environment, collectively referred to as the "source term." The source term can vary in magnitude based upon the total quantity of radioactive material present in a PIPET or GTA core (the total inventory), and the fractional amounts of each nuclide that escapes to the environment during any given operation or accident.

The total inventory present in a PIPET or GTA core consists of three groups:

- Unburned (unfissioned) reactor fuel consisting of 93 percent enriched uranium
- Fission products accumulated during reactor operations as a result of the fissioning the reactor fuel
- Activation products produced during reactor operations from the interaction of neutrons with core structural materials and coolant, creating radioactive isotopes of the materials (referred to as neutron "activation").

Since fission products will account for greater than 99 percent of radiological impacts, determination of source terms used in this analysis will be based on calculated fission product inventories only, except for

Consequence I accidents (see below), which will also include activation products.

Fission Product Inventories

The fission product inventory present in a reactor is primarily dependent upon the total operating time and output thermal energies at which the core has been operated, and is referred to as the core "operational power history." This is used to provide a means of expressing the total amount of energy produced in a core, which corresponds to how long and how heavily the core has been operated. Core power history may be expressed in terms of total thermal energy produced in the core, which is the product of operational thermal power in MW times the total operating time in seconds, and is expressed in terms of MW-seconds, or MJ. Since the numbers which result from this calculation are often quite large, it is more common to express the final operational power history in units of terajoules (TJ) (1 TJ equals 1 million MJ) to yield numbers which are less cumbersome.

Increases in the total operational power history increase the fission product inventory in an approximately linear fashion (i.e., a doubling of the total energy produced will approximately double the total fission product inventory). For purposes of this assessment, the following test operation maximum power and duration values for PIPET and GTA are used:

- PIPET: Five operations of 550 MW for 500 seconds each, for a total of 1.375 TJ total energy produced
- GTA: 2,000 MW operational power for 1,000 seconds for a total of 2.0 TJ total energy produced.

Determinations were also made as to the maximum 1-year operational scenario that might be expected. This was determined to be operation of two PIPET cores, each operated for five tests (maximum case tests as expressed above) with a 1-week interval between tests and two GTA cores, each operated for one maximum case test (again, as above). One of the 10 PIPET tests was assumed to be a Normal III experiment. This assumed scenario does not preclude other annual operational scenarios, as long as the source terms capable of being released in alternative scenarios do not exceed those evaluated using the above. Once a PBR propulsion technology reactor core has reached these source term limits it will be taken out of service.

The radiological inventory resulting from these operational histories was generated using the ORIGEN2 computer program, and consists of fission and activation products generated during reactor operation. ORIGEN2 is a code specifically developed by Oak Ridge National Laboratories for the nuclear power industry, to calculate fission product build-up and inventories in

operational reactors. Example core inventories for 639 isotopes resulting from a single maximum case operation of a PIPET and GTA core are listed in Tables E-3 and E-4, respectively.

Source Term Development

Core inventory constituents would originate primarily within the fuel particles, mainly in the uranium kernel. The fuel particles would, therefore, serve as the primary containment. A small quantity of some constituents (such as noble gases and other "volatiles") would be able to escape directly from the fuel particles; additional releases may occur due to failure of a small number of fuel particles. In the event of an accident, a larger amount may escape. Radioactive materials escaping the reactor core will enter the ETS, which is designed to contain such releases, allowing only small quantities of material to escape. The quantities of various nuclides that actually escape to the environment are collectively referred to as the "source term," and can vary in magnitude from a fractional amount of the total core inventory (the case for Normal II operations), to the entire inventory (as for a Consequence I accident).

Of the total isotope inventories for PIPET and GTA, the release fractions for 55 have been expressly calculated for a Normal II operation (see Section 2.2 for explanation of Normal II) (Young, 1992). Release routes for intact particles were calculated based on literature values of diffusion rates in coated fuel particles. Failed fuel releases were based on experimental measurements assuming 1 percent fuel failure rate. Table E-5 presents specific release quantities for these 55 nuclides, which were identified as the major contributors to the radiological consequences.

Assumptions have been made to estimate the release fractions of the remaining isotope inventory during a Normal II operation. The majority of these remaining isotopes are largely non-volatile, and in general, have small diffusion release rates thought to be less than 1 percent in general. A few of the highly mobile isotopes show higher fractional releases of up to 12 percent (e.g., cesium and strontium). Accordingly, the remaining noble gas, halogen, and non-volatile species are assigned fractional releases as shown in Table E-6. These have been determined by combining the inventory isotopes into four groups based upon their chemical similarities. Additionally, all isotope release fractions are incremented an additional 1 percent to conservatively account for unanticipated fuel failures (Young, 1992).

In addition to fuel particle releases, ETS design goal retention efficiencies of 99.9 percent for particulates and 99.5 percent for volatiles, halogens, and nobles are assumed in calculating final release values. These represent industry acceptable standards and are the baseline efficiencies toward which the current ETS is being designed. The corresponding ETS particulate

Table E-3. PIPET Fission and Activation Product Inventory 550 MW, 500 Second Operation
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Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
¹⁰⁸ Ag	2.404 x 10 ⁵	⁸⁶ Br	3.394 x 10 ¹	⁶⁰ Cu	3.243 x 10 ⁰	¹³⁶ I	3.387 x 10 ⁶	²⁸ Mg	7.541 x 10 ⁻⁶
^{109m} Ag	2.228 x 10 ¹²	⁹⁶ Br	1.549 x 10 ⁰	⁶¹ Cu	1.696 x 10 ⁻¹	¹⁴⁰ I	9.950 x 10 ⁵	¹⁰¹ Mo	7.435 x 10 ⁶
¹⁰⁹ Ag	6.014 x 10 ²	¹⁴ C	1.147 x 10 ⁻⁸	¹⁶⁵ Dy	5.476 x 10 ⁻¹	¹⁴¹ I	1.420 x 10 ⁵	¹⁰³ Mo	1.391 x 10 ⁷
¹¹⁰ Ag	1.189 x 10 ¹	^{113m} Cd	4.213 x 10 ⁻⁴	^{166m} Dy	8.805 x 10 ⁰	¹⁴² I	1.029 x 10 ⁴	¹⁰⁴ Mo	8.191 x 10 ⁶
^{110m} Ag	3.180 x 10 ⁷	¹¹⁵ Cd	3.436 x 10 ¹	¹⁶⁶ Dy	1.184 x 10 ⁻²	¹⁴³ I	4.197 x 10 ²	¹⁰⁶ Mo	4.289 x 10 ⁶
¹¹¹ Ag	3.591 x 10 ⁰	^{115m} Cd	4.334 x 10 ⁻¹	¹⁶⁸ Er	1.763 x 10 ⁻¹¹	¹⁴⁴ I	1.592 x 10 ¹	¹⁰⁸ Mo	1.687 x 10 ⁶
^{111m} Ag	1.759 x 10 ⁴	¹¹⁷ Cd	1.599 x 10 ³	¹⁵⁰ Eu	1.392 x 10 ⁻⁸	^{113m} In	9.162 x 10 ⁻⁷	¹⁰⁷ Mo	6.240 x 10 ⁵
¹¹² Ag	2.994 x 10 ¹	^{117m} Cd	6.799 x 10 ²	¹⁵² Eu	9.507 x 10 ⁻⁷	¹¹⁴ In	8.215 x 10 ⁻⁵	¹⁰⁸ Mo	1.897 x 10 ⁴
¹¹³ Ag	1.025 x 10 ³	¹¹⁹ Cd	1.793 x 10 ⁴	^{153m} Eu	4.949 x 10 ⁻³	^{114m} In	6.561 x 10 ⁻⁸	¹¹¹ Mo	1.767 x 10 ²
^{113m} Ag	7.973 x 10 ³	^{119m} Cd	3.262 x 10 ⁴	¹⁵⁴ Eu	1.037 x 10 ⁻⁵	^{115m} In	3.551 x 10 ⁻¹	¹¹² Mo	1.962 x 10 ¹
¹¹⁵ Ag	1.186 x 10 ⁴	¹²¹ Cd	7.936 x 10 ⁴	^{154m} Eu	3.819 x 10 ⁻²	¹¹⁶ In	9.657 x 10 ⁻²	¹¹³ Mo	1.278 x 10 ⁰
^{115m} Ag	2.051 x 10 ⁴	¹²³ Cd	7.018 x 10 ⁴	¹⁵⁶ Eu	1.476 x 10 ⁻¹	^{116m} In	9.741 x 10 ⁻³	¹¹⁵ Mo	3.025 x 10 ⁻³
¹¹⁷ Ag	3.707 x 10 ⁴	¹²⁶ Cd	3.661 x 10 ⁴	¹⁵⁷ Eu	5.731 x 10 ¹	¹¹⁷ In	3.051 x 10 ¹	⁹⁸ Mo	3.791 x 10 ⁴
^{117m} Ag	3.796 x 10 ⁴	^{126m} Cd	3.791 x 10 ⁴	¹⁵⁸ Eu	2.691 x 10 ²	^{117m} In	4.032 x 10 ¹	²⁴ Na	1.054 x 10 ²
¹¹⁹ Ag	5.863 x 10 ⁴	¹²⁷ Cd	1.892 x 10 ⁴	¹⁵⁹ Eu	1.134 x 10 ³	¹¹⁹ In	1.219 x 10 ⁴	¹⁰¹ Nb	2.287 x 10 ⁷
¹²¹ Ag	2.360 x 10 ⁴	¹²⁸ Cd	8.401 x 10 ³	¹⁶¹ Eu	5.377 x 10 ²	^{119m} In	5.880 x 10 ³	¹⁰³ Nb	1.018 x 10 ⁷
¹²³ Ag	6.021 x 10 ³	¹²⁹ Cd	1.421 x 10 ³	¹⁶⁵ Eu	5.999 x 10 ⁻¹	¹²¹ In	6.796 x 10 ⁴	¹⁰⁴ Nb	3.739 x 10 ⁶
¹²⁵ Ag	6.477 x 10 ²	¹³⁰ Cd	3.738 x 10 ³	⁷² Ga	3.550 x 10 ⁻³	^{121m} In	1.498 x 10 ⁴	¹⁰⁶ Nb	9.822 x 10 ⁵
¹²⁶ Ag	2.474 x 10 ²	¹³¹ Cd	3.565 x 10 ²	⁷³ Ga	2.078 x 10 ¹	¹²³ In	6.882 x 10 ⁴	¹⁰⁶ Nb	3.336 x 10 ⁵
¹²⁸ Ag	6.441 x 10 ⁰	¹³² Cd	2.846 x 10 ¹	⁷⁶ Ga	6.636 x 10 ³	^{123m} In	3.056 x 10 ⁴	¹⁰⁷ Nb	5.302 x 10 ⁴
²⁶ Al	1.745 x 10 ⁶	¹⁴¹ Ce	3.895 x 10 ⁰	⁷⁷ Ga	4.167 x 10 ⁴	¹²⁶ In	6.231 x 10 ⁴	¹⁰⁸ Nb	1.206 x 10 ²
²⁹ Al	2.376 x 10 ¹⁰	¹⁴³ Ce	1.404 x 10 ⁴	⁷⁸ Ga	8.509 x 10 ⁴	^{126m} In	4.767 x 10 ⁴	¹¹¹ Nb	1.397 x 10 ⁻¹
⁷⁶ As	2.793 x 10 ³	¹⁴⁴ Ce	3.029 x 10 ²	⁷⁹ Ga	7.757 x 10 ⁴	¹²⁸ In	2.217 x 10 ⁵	⁹³ Nb	3.481 x 10 ⁻⁶
⁷⁷ As	6.214 x 10 ¹	¹⁴⁵ Ce	1.401 x 10 ⁷	⁸⁰ Ga	1.015 x 10 ⁵	¹²⁷ In	1.241 x 10 ⁵	⁹⁴ Nb	1.459 x 10 ⁻⁶
⁷⁸ As	2.504 x 10 ²	¹⁴⁷ Ce	1.003 x 10 ⁷	⁸¹ Ga	5.399 x 10 ⁴	^{127m} In	1.246 x 10 ⁵	^{94m} Nb	1.214 x 10 ⁰
⁷⁹ As	1.035 x 10 ⁵	¹⁴⁹ Ce	3.594 x 10 ⁶	⁸³ Ga	4.397 x 10 ³	^{128m} In	2.938 x 10 ⁵	⁹⁶ Nb	2.525 x 10 ⁻²
⁸¹ As	9.410 x 10 ⁵	¹⁵¹ Ce	3.530 x 10 ⁵	⁸⁴ Ga	2.533 x 10 ²	¹²⁹ In	1.829 x 10 ⁵	^{96m} Nb	6.605 x 10 ⁻¹
⁸³ As	1.942 x 10 ⁶	¹⁵³ Ce	6.059 x 10 ³	¹⁵³ Gd	7.512 x 10 ⁻¹⁰	¹³⁰ In	3.416 x 10 ⁵	⁹⁸ Nb	1.117 x 10 ¹
⁸⁴ As	1.460 x 10 ⁶	¹⁵⁵ Ce	1.572 x 10 ¹	¹⁵⁶ Gd	2.837 x 10 ⁰	¹³¹ In	1.127 x 10 ⁵	⁹⁷ Nb	1.234 x 10 ⁴
⁸⁵ As	9.544 x 10 ⁵	¹⁵⁶ Ce	4.262 x 10 ⁻¹	¹⁶¹ Gd	4.622 x 10 ²	¹³² In	3.052 x 10 ⁴	^{97m} Nb	1.512 x 10 ⁵
⁸⁶ As	5.251 x 10 ⁵	¹⁵⁷ Ce	1.185 x 10 ⁻²	¹⁶⁵ Gd	1.045 x 10 ¹	¹³³ In	1.824 x 10 ³	⁹⁸ Nb	2.679 x 10 ⁷
⁸⁷ As	2.971 x 10 ⁵	⁷² Co	4.125 x 10 ⁰	⁷⁵ Ge	3.256 x 10 ²	¹³⁴ In	3.247 x 10 ¹	^{98m} Nb	1.328 x 10 ⁴
⁸⁸ As	1.212 x 10 ⁴	⁷³ Co	4.326 x 10 ⁻¹	^{76m} Ge	2.749 x 10 ²	⁸¹ Kr	4.126 x 10 ⁻¹³	⁹⁹ Nb	2.689 x 10 ⁷
⁸⁹ As	9.538 x 10 ²	⁷⁵ Co	4.463 x 10 ⁻²	⁷⁷ Ge	1.240 x 10 ²	^{81m} Kr	4.106 x 10 ⁻³	^{99m} Nb	6.112 x 10 ⁵
^{136m} Ba	4.639 x 10 ³	¹³² Cs	5.382 x 10 ⁻⁹	^{77m} Ge	3.738 x 10 ⁴	⁸³ Kr	1.132 x 10 ³	¹⁴⁷ Nd	4.912 x 10 ²
¹³⁸ Ba	4.817 x 10 ⁵	¹³⁴ Cs	3.492 x 10 ⁻⁴	⁷⁸ Ge	5.980 x 10 ⁻³	⁸⁴ Kr	2.156 x 10 ⁻²	¹⁴⁹ Nd	1.742 x 10 ⁵
¹⁴⁰ Ba	7.273 x 10 ³	^{134m} Cs	4.087 x 10 ⁰	⁷⁹ Ge	2.007 x 10 ⁵	^{85m} Kr	6.619 x 10 ⁴	¹⁵¹ Nd	7.130 x 10 ⁵
¹⁴¹ Ba	6.933 x 10 ⁶	¹³⁶ Cs	2.153 x 10 ⁻⁸	⁸¹ Ge	6.659 x 10 ⁵	⁸⁷ Kr	7.465 x 10 ⁵	¹⁵³ Nd	6.811 x 10 ⁵
¹⁴² Ba	1.107 x 10 ⁷	^{136m} Cs	2.970 x 10 ²	⁸³ Ge	4.525 x 10 ⁵	⁸⁸ Kr	5.405 x 10 ⁵	¹⁵⁵ Nd	8.236 x 10 ⁴
¹⁴³ Ba	2.433 x 10 ⁷	¹³⁸ Cs	1.023 x 10 ¹	⁸⁴ Ge	8.819 x 10 ⁴	⁸⁹ Kr	1.773 x 10 ⁷	¹⁵⁶ Nd	1.633 x 10 ⁴
¹⁴⁴ Ba	1.954 x 10 ⁷	¹³⁷ Cs	4.914 x 10 ⁰	⁸⁶ Ge	2.964 x 10 ⁴	⁹⁰ Kr	2.115 x 10 ⁷	¹⁵⁷ Nd	2.762 x 10 ³
¹⁴⁶ Ba	9.151 x 10 ⁶	^{138m} Cs	1.172 x 10 ⁶	⁸⁸ Ge	5.248 x 10 ³	⁹¹ Kr	1.560 x 10 ⁷	¹⁵⁸ Nd	3.096 x 10 ²
¹⁴⁷ Ba	6.011 x 10 ⁵	¹³⁹ Cs	9.854 x 10 ⁵	⁸⁷ Ge	8.422 x 10 ²	⁹² Kr	6.828 x 10 ⁶	¹⁵⁹ Nd	1.454 x 10 ¹
¹⁴⁹ Ba	4.284 x 10 ³	¹⁴⁰ Cs	1.227 x 10 ⁷	⁸⁸ Ge	9.604 x 10 ⁰	⁹³ Kr	2.322 x 10 ⁶	¹⁶¹ Nd	1.198 x 10 ⁻²
¹⁰ Be	5.759 x 10 ⁶	¹⁴¹ Cs	2.033 x 10 ⁷	³ H	6.429 x 10 ⁻²	⁹⁴ Kr	1.046 x 10 ⁶	⁷² Ni	1.359 x 10 ²
⁸⁰ Br	4.969 x 10 ¹	¹⁴² Cs	1.307 x 10 ⁷	¹⁶⁶ Ho	7.423 x 10 ⁻⁸	⁹⁵ Kr	4.705 x 10 ⁴	⁷³ Ni	6.965 x 10 ¹
^{80m} Br	2.836 x 10 ²	¹⁴³ Cs	7.000 x 10 ⁶	^{168m} Ho	1.253 x 10 ⁻¹⁰	⁹⁶ Kr	7.699 x 10 ³	⁷⁵ Ni	4.592 x 10 ¹
⁸² Br	1.060 x 10 ⁰			¹²⁸ I	1.121 x 10 ¹	⁹⁷ Kr	1.879 x 10 ²	⁷⁷ Ni	2.081 x 10 ⁰

Table E-3. PIPET Fission and Activation Product Inventory 550 MW, 500 Second Operation
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Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
⁸⁴ Br	4.218 x 10 ⁵	¹⁴⁶ Cs	3.738 x 10 ⁴	^{130m} I	1.715 x 10 ²	¹⁴¹ La	9.079 x 10 ⁴	²³⁷ Np	1.184 x 10 ⁻¹¹
⁸⁶ Br	4.835 x 10 ⁶	¹⁴⁷ Cs	2.730 x 10 ³	¹³¹ I	7.985 x 10 ¹	¹⁴² La	3.958 x 10 ⁵	²³⁸ Np	5.801 x 10 ⁻⁷
⁸⁷ Br	9.884 x 10 ⁶	⁶⁶ Cu	1.587 x 10 ⁻³	¹³² I	4.193 x 10 ³	¹⁴³ La	8.778 x 10 ⁶	²³⁹ Np	1.279 x 10 ²
⁸⁸ Br	1.150 x 10 ⁷	⁶⁷ Cu	2.205 x 10 ⁻¹⁰	¹³³ I	1.919 x 10 ⁴	¹⁴⁴ La	2.465 x 10 ⁷	²⁴⁰ Np	3.459 x 10 ⁻¹
⁸⁹ Br	8.686 x 10 ⁶	⁷² Cu	2.909 x 10 ²	^{133m} I	5.934 x 10 ⁵	¹⁴⁵ La	1.693 x 10 ⁷	^{240m} Np	6.718 x 10 ⁻¹
⁹⁰ Br	5.852 x 10 ⁶	⁷³ Cu	5.243 x 10 ²	¹³⁴ I	5.406 x 10 ⁵	¹⁴⁷ La	4.912 x 10 ⁶	²⁴¹ Np	1.311 x 10 ⁻⁵
⁹¹ Br	1.814 x 10 ⁶	⁷⁶ Cu	1.294 x 10 ³	^{134m} I	1.643 x 10 ⁶	¹⁴⁸ La	3.274 x 10 ⁵	²³² Pa	2.029 x 10 ⁻¹¹
⁹² Br	8.728 x 10 ⁴	⁷⁷ Cu	5.409 x 10 ²	¹³⁶ I	4.056 x 10 ⁵	¹⁵¹ La	4.130 x 10 ³	²³⁴ Pa	1.587 x 10 ⁻¹⁰
⁹³ Br	2.168 x 10 ⁴	⁷⁸ Cu	2.051 x 10 ²	¹³⁷ I	1.500 x 10 ⁷	¹⁵³ La	6.949 x 10 ⁰	¹⁰⁷ Pd	5.677 x 10 ⁻⁶
⁹⁴ Br	1.506 x 10 ³	⁷⁹ Cu	2.392 x 10 ¹	¹³⁸ I	7.625 x 10 ⁶	²⁷ Mg	3.598 x 10 ⁴	^{107m} Pd	3.554 x 10 ⁻³
¹⁰⁰ Pd	6.017 x 10 ²	⁸⁴ Rb	8.131 x 10 ⁶	^{138m} Sb	2.741 x 10 ¹	⁸⁴ Sr	2.675 x 10 ⁷	¹³³ Xe	3.105 x 10 ⁰
^{100m} Pd	5.029 x 10 ⁴	⁸⁶ Rb	4.169 x 10 ⁶	⁷⁶ Se	3.583 x 10 ⁻⁶	⁸⁶ Sr	2.502 x 10 ⁷	^{133m} Xe	3.580 x 10 ¹
¹¹¹ Pd	2.242 x 10 ⁴	⁸⁶ Rb	9.282 x 10 ⁵	^{78m} Se	5.367 x 10 ⁴	⁸⁷ Sr	8.880 x 10 ⁶	¹³⁶ Xe	2.727 x 10 ³
^{111m} Pd	1.659 x 10 ¹	⁸⁷ Rb	1.677 x 10 ⁵	⁸¹ Se	2.270 x 10 ⁵	⁸⁸ Sr	3.231 x 10 ⁶	^{136m} Xe	2.566 x 10 ⁵
¹¹² Pd	4.101 x 10 ²	⁸⁸ Rb	2.426 x 10 ⁴	^{81m} Se	3.022 x 10 ³	⁹⁰ Sr	7.102 x 10 ⁵	¹³⁷ Xe	2.068 x 10 ⁷
¹¹³ Pd	8.275 x 10 ⁴	⁸⁸ Rb	1.872 x 10 ³	⁸³ Se	2.027 x 10 ⁵	¹⁰⁰ Tb	2.463 x 10 ⁻⁵	¹³⁸ Xe	9.581 x 10 ⁶
¹¹⁵ Pd	6.992 x 10 ⁴	^{100m} Rh	5.060 x 10 ¹	^{83m} Se	1.477 x 10 ⁶	¹⁶¹ Tb	1.695 x 10 ⁻¹	^{138m} Xe	2.338 x 10 ⁷
¹¹⁷ Pd	7.283 x 10 ⁴	¹⁰⁴ Rh	3.067 x 10 ⁻¹	⁸⁴ Se	3.760 x 10 ⁶	¹⁶⁵ Tb	1.813 x 10 ¹	¹⁴⁰ Xe	1.634 x 10 ⁷
¹¹⁹ Pd	1.593 x 10 ⁴	^{104m} Rh	1.291 x 10 ⁻¹	⁸⁵ Se	2.900 x 10 ⁶	¹⁰¹ Tc	1.408 x 10 ⁶	¹⁴¹ Xe	5.416 x 10 ⁶
¹²¹ Pd	1.379 x 10 ³	¹⁰⁶ Rh	8.359 x 10 ¹	^{86m} Se	2.116 x 10 ⁶	¹⁰² Tc	1.399 x 10 ⁷	¹⁴² Xe	1.759 x 10 ⁶
¹²³ Pd	7.330 x 10 ¹	^{106m} Rh	6.473 x 10 ³	⁸⁷ Se	4.502 x 10 ⁶	¹⁰⁴ Tc	1.793 x 10 ⁶	¹⁴³ Xe	2.398 x 10 ⁵
¹²⁶ Pd	1.800 x 10 ⁻¹	¹⁰⁸ Rh	4.049 x 10 ⁰	⁸⁸ Se	1.646 x 10 ⁶	¹⁰⁶ Tc	2.175 x 10 ⁶	¹⁴⁴ Xe	3.029 x 10 ⁴
¹⁴⁶ Pm	2.875 x 10 ⁻¹²	¹⁰⁷ Rh	8.891 x 10 ⁴	⁸⁸ Se	4.278 x 10 ⁵	¹⁰⁸ Tc	1.917 x 10 ⁶	¹⁴⁵ Xe	6.890 x 10 ²
¹⁴⁷ Pm	6.232 x 10 ⁻⁴	¹⁰⁸ Rh	1.823 x 10 ⁵	⁹⁰ Se	1.482 x 10 ⁵	¹⁰⁷ Tc	8.719 x 10 ⁵	¹⁴⁶ Xe	6.403 x 10 ¹
¹⁴⁸ Pm	1.740 x 10 ⁻²	^{108m} Rh	1.028 x 10 ⁵	⁹¹ Se	1.483 x 10 ⁴	¹⁰⁹ Tc	1.157 x 10 ⁵	¹⁴⁷ Xe	1.127 x 10 ⁰
^{148m} Pm	3.265 x 10 ⁻⁴	¹¹¹ Rh	1.157 x 10 ⁵	⁹² Se	2.206 x 10 ²	¹¹¹ Tc	1.180 x 10 ⁴	¹⁰¹ Y	1.252 x 10 ⁶
¹⁴⁹ Pm	1.251 x 10 ²	¹¹² Rh	8.288 x 10 ⁴	¹⁵¹ Sm	5.861 x 10 ⁻⁵	¹¹² Tc	2.492 x 10 ³	¹⁰³ Y	2.463 x 10 ⁴
¹⁵⁰ Pm	8.308 x 10 ¹	¹¹³ Rh	7.103 x 10 ⁴	¹⁵² Sm	4.521 x 10 ²	¹¹³ Tc	5.443 x 10 ²	¹⁰⁴ Y	1.173 x 10 ³
¹⁵¹ Pm	1.328 x 10 ³	¹¹⁵ Rh	2.645 x 10 ⁴	¹⁵⁴ Sm	3.300 x 10 ⁴	¹¹⁵ Tc	6.846 x 10 ⁰	¹⁰⁶ Y	1.037 x 10 ²
¹⁵³ Pm	4.392 x 10 ⁵	¹¹⁷ Rh	2.793 x 10 ⁴	¹⁵⁶ Sm	6.584 x 10 ²	¹¹⁷ Tc	5.325 x 10 ⁻²	¹⁰⁷ Y	1.721 x 10 ⁻¹
¹⁵⁵ Pm	1.546 x 10 ⁵	¹¹⁹ Rh	1.989 x 10 ²	¹⁵⁷ Sm	1.650 x 10 ⁴	⁹⁹ Tc	1.357 x 10 ⁻⁷	⁹⁰ Y	1.980 x 10 ¹
¹⁵⁶ Pm	5.334 x 10 ⁴	¹²¹ Rh	2.497 x 10 ⁰	¹⁵⁸ Sm	2.083 x 10 ³	^{99m} Tc	2.632 x 10 ²	^{90m} Y	1.745 x 10 ⁰
¹⁵⁷ Pm	1.860 x 10 ⁴	¹²³ Rh	2.393 x 10 ⁻²	¹⁶⁰ Sm	4.264 x 10 ³	^{123m} Te	2.283 x 10 ⁻⁶	⁹¹ Y	3.157 x 10 ⁰
¹⁵⁸ Pm	5.102 x 10 ³	¹⁰⁰ Ru	1.174 x 10 ³	¹⁶¹ Sm	1.911 x 10 ²	^{125m} Te	4.454 x 10 ⁻⁵	^{91m} Y	6.524 x 10 ³
¹⁵⁹ Pm	6.755 x 10 ²	¹⁰⁶ Ru	2.310 x 10 ⁴	¹⁶⁵ Sm	5.153 x 10 ⁻³	¹²⁷ Te	3.123 x 10 ⁰	⁹² Y	1.412 x 10 ⁴
¹⁶¹ Pm	3.845 x 10 ⁰	¹⁰⁸ Ru	1.824 x 10 ¹	^{117m} Sn	9.030 x 10 ⁻⁶	^{127m} Te	1.544 x 10 ⁻²	⁹³ Y	8.773 x 10 ⁴
¹⁴² Pr	8.272 x 10 ⁻⁴	¹⁰⁷ Ru	6.013 x 10 ⁵	^{118m} Sn	3.797 x 10 ⁻²	¹²⁸ Te	6.599 x 10 ³	⁹⁴ Y	6.085 x 10 ⁶
^{142m} Pr	4.586 x 10 ⁻²	¹⁰⁹ Ru	2.027 x 10 ⁵	¹²¹ Sn	2.494 x 10 ²	^{129m} Te	6.852 x 10 ⁰	⁹⁵ Y	1.164 x 10 ⁷
¹⁴³ Pr	1.452 x 10 ⁰	¹¹¹ Ru	9.482 x 10 ⁴	^{121m} Sn	8.076 x 10 ⁻⁶	¹³¹ Te	3.564 x 10 ⁵	⁹⁷ Y	2.324 x 10 ⁷
¹⁴⁴ Pr	1.880 x 10 ²	¹¹² Ru	4.821 x 10 ⁴	¹²³ Sn	7.373 x 10 ⁻¹	^{131m} Te	3.087 x 10 ³	⁹⁸ Y	1.665 x 10 ⁷
^{144m} Pr	8.681 x 10 ¹	¹¹³ Ru	2.608 x 10 ⁴	^{123m} Sn	1.038 x 10 ⁴	¹³² Te	1.673 x 10 ⁴	⁹⁹ Y	9.268 x 10 ⁶
¹⁴⁶ Pr	1.461 x 10 ⁵	¹¹⁵ Ru	2.252 x 10 ³	¹²⁶ Sn	2.957 x 10 ¹	¹³³ Te	4.746 x 10 ⁶	⁷² Zn	6.538 x 10 ⁻¹
¹⁴⁷ Pr	3.006 x 10 ⁶	¹¹⁷ Ru	2.210 x 10 ²	^{126m} Sn	4.970 x 10 ⁴	^{133m} Te	1.326 x 10 ⁶	⁷³ Zn	1.113 x 10 ³
¹⁴⁸ Pr	4.513 x 10 ⁶	¹²² Sb	4.626 x 10 ⁻⁴	¹²⁶ Sn	3.643 x 10 ⁻⁵	¹³⁴ Te	3.984 x 10 ⁶	⁷⁶ Zn	6.311 x 10 ³
¹⁵¹ Pr	1.384 x 10 ⁶	^{123m} Sb	1.623 x 10 ⁻¹	¹²⁷ Sn	2.082 x 10 ⁴	¹³⁶ Te	1.514 x 10 ⁷	⁷⁷ Zn	1.720 x 10 ⁴
¹⁵³ Pr	1.502 x 10 ⁵	¹²⁴ Sb	3.353 x 10 ⁻³	^{127m} Sn	1.747 x 10 ⁵	¹³⁸ Te	8.650 x 10 ⁶	⁷⁸ Zn	1.976 x 10 ⁴

Table E-3. PIPET Fission and Activation Product Inventory 550 MW, 500 Second Operation
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Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
¹⁵⁷ Pr	1.485 x 10 ¹	¹²⁶ Sb	1.433 x 10 ⁰	¹²⁰ Sn	1.453 x 10 ⁶	¹³⁶ Te	5.994 x 10 ⁴	⁸¹ Zn	6.082 x 10 ²
¹⁵⁸ Pr	5.958 x 10 ⁻¹	¹²⁸ Sb	6.056 x 10 ²	¹²¹ Sn	4.497 x 10 ⁶	¹⁴⁰ Te	5.583 x 10 ³	⁸² Zn	4.705 x 10 ⁰
¹⁵⁹ Pr	9.899 x 10 ⁻³	¹²⁷ Sb	1.583 x 10 ²	¹²² Sn	2.727 x 10 ⁶	¹⁴¹ Te	1.936 x 10 ²	¹⁰¹ Zr	1.597 x 10 ⁷
²³⁸ Pu	1.984 x 10 ⁻⁸	¹²⁸ Sb	7.827 x 10 ²	¹³³ Sn	7.797 x 10 ⁵	¹⁴² Te	3.802 x 10 ⁰	¹⁰² Zr	2.446 x 10 ⁶
²⁴⁰ Pu	4.604 x 10 ⁻¹⁰	¹²⁹ Sb	4.022 x 10 ⁴	¹³⁴ Sn	5.490 x 10 ⁴	²³¹ Th	4.297 x 10 ⁻⁵	¹⁰⁴ Zr	3.701 x 10 ⁵
²⁴¹ Pu	1.115 x 10 ⁻¹⁰	¹³⁰ Sb	1.349 x 10 ⁵	¹³⁵ Sn	5.721 x 10 ³	²³² Th	8.292 x 10 ⁻¹¹	¹⁰⁶ Zr	4.755 x 10 ⁴
⁸⁶ Rb	6.876 x 10 ⁻²	¹³¹ Sb	2.461 x 10 ⁶	¹³⁶ Sn	2.518 x 10 ²	²³⁴ Th	2.225 x 10 ⁻⁸	¹⁰⁸ Zr	1.141 x 10 ⁴
⁸⁸ Rb	2.531 x 10 ⁻²	¹³² Sb	6.445 x 10 ⁶	¹⁰¹ Sr	1.364 x 10 ⁴	²³³ U	8.074 x 10 ⁻¹⁰	¹⁰⁷ Zr	5.478 x 10 ²
⁸⁷ Rb	8.196 x 10 ⁻¹¹	¹³³ Sb	3.679 x 10 ⁶	¹⁰² Sr	2.217 x 10 ¹	²³⁴ U	1.217 x 10 ⁻⁸	¹⁰⁹ Zr	8.323 x 10 ⁻²
⁸⁹ Rb	1.202 x 10 ⁵	¹³⁴ Sb	9.416 x 10 ⁶	¹⁰⁴ Sr	3.826 x 10 ⁻¹	²³⁵ U	1.141 x 10 ⁻²	⁹³ Zr	2.351 x 10 ⁻⁷
⁹⁰ Rb	4.023 x 10 ⁶	^{134m} Sb	1.242 x 10 ⁶	^{87m} Sr	1.523 x 10 ⁻¹	²³⁶ U	4.841 x 10 ⁻⁵	⁹⁶ Zr	4.066 x 10 ²
⁹⁰ Rb	1.796 x 10 ⁷	¹³⁵ Sb	1.187 x 10 ⁶	⁸⁸ Sr	1.291 x 10 ²	²³⁷ U	5.693 x 10 ⁰	⁹⁷ Zr	1.528 x 10 ⁵
⁹⁰ Rb	3.183 x 10 ⁶	¹³⁶ Sb	9.078 x 10 ⁵	⁹⁰ Sr	5.307 x 10 ⁰	²³⁸ U	1.337 x 10 ⁻⁴	⁹⁸ Zr	2.658 x 10 ⁷
⁹¹ Rb	2.541 x 10 ⁷	¹³⁶ Sb	1.379 x 10 ⁵	⁹¹ Sr	2.247 x 10 ⁵	²³⁹ U	1.444 x 10 ⁵	⁹⁹ Zr	2.626 x 10 ⁷
⁹² Rb	2.189 x 10 ⁷	¹³⁷ Sb	9.832 x 10 ²	⁹² Sr	9.517 x 10 ⁵	²⁴⁰ U	1.067 x 10 ⁻¹		
⁹³ Rb	1.623 x 10 ⁷	¹³⁸ Sb	6.124 x 10 ²	⁹³ Sr	1.559 x 10 ⁷	²⁴¹ U	1.170 x 10 ⁻⁴		

Table E-4. GTA Fission and Activation Product Inventory 2 GW, 1,000 Second Operation

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Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
¹⁰⁸ Ag	1.099 x 10 ⁻⁴	⁹⁶ Br	1.234 x 10 ²	⁸⁰ Cu	1.179 x 10 ¹	¹³⁸ I	1.231 x 10 ⁷	²⁸ Mg	6.328 x 10 ⁻⁵
^{108m} Ag	1.620 x 10 ⁻¹¹	^{96m} Br	5.631 x 10 ⁰	⁸¹ Cu	6.166 x 10 ⁻¹	¹⁴⁰ I	3.618 x 10 ⁶	¹⁰¹ Mo	4.586 x 10 ⁷
^{108m} Ag	6.435 x 10 ⁻³	¹⁴ C	8.341 x 10 ⁻⁶	¹⁶⁵ Dy	4.522 x 10 ⁰	¹⁴¹ I	5.162 x 10 ⁶	¹⁰² Mo	5.243 x 10 ⁷
¹¹⁰ Ag	2.108 x 10 ⁰	^{113m} Cd	3.591 x 10 ⁻³	^{165m} Dy	3.573 x 10 ¹	¹⁴² I	3.741 x 10 ⁴	¹⁰⁴ Mo	3.066 x 10 ⁷
^{110m} Ag	3.254 x 10 ⁻⁶	¹¹⁶ Cd	3.400 x 10 ²	¹⁶⁶ Dy	8.655 x 10 ⁻²	¹⁴³ I	1.526 x 10 ³	¹⁰⁶ Mo	1.564 x 10 ⁷
¹¹¹ Ag	8.655 x 10 ¹	^{116m} Cd	3.513 x 10 ⁰	^{166m} Er	2.427 x 10 ⁻¹⁰	¹⁴⁴ I	5.789 x 10 ¹	¹⁰⁸ Mo	6.135 x 10 ⁶
^{111m} Ag	1.585 x 10 ⁶	¹¹⁷ Cd	1.185 x 10 ⁴	¹⁶⁰ Eu	1.387 x 10 ⁻⁷	^{113m} In	6.476 x 10 ⁻⁶	¹⁰⁷ Mo	2.269 x 10 ⁶
¹¹² Ag	2.602 x 10 ²	^{117m} Cd	5.095 x 10 ³	¹⁶² Eu	9.482 x 10 ⁻⁶	¹¹⁴ In	3.013 x 10 ⁻⁴	¹⁰⁸ Mo	6.898 x 10 ⁴
^{112m} Ag	8.618 x 10 ³	¹¹⁸ Cd	1.011 x 10 ⁶	^{163m} Eu	4.885 x 10 ⁻²	^{114m} In	4.772 x 10 ⁻⁸	¹¹¹ Mo	6.423 x 10 ²
^{113m} Ag	3.113 x 10 ⁴	^{118m} Cd	1.391 x 10 ⁵	¹⁶⁴ Eu	7.782 x 10 ⁻⁶	^{115m} In	6.401 x 10 ⁰	¹¹² Mo	7.132 x 10 ¹
¹¹⁵ Ag	8.016 x 10 ⁴	¹²¹ Cd	2.885 x 10 ⁶	¹⁶⁶ Eu	5.509 x 10 ⁻¹	¹¹⁶ In	3.562 x 10 ⁻¹	¹¹³ Mo	4.649 x 10 ⁰
^{115m} Ag	7.456 x 10 ⁴	¹²² Cd	2.552 x 10 ⁶	^{166m} Eu	1.855 x 10 ⁰	^{116m} In	6.749 x 10 ⁻²	¹¹⁵ Mo	1.100 x 10 ⁻²
¹¹⁷ Ag	1.380 x 10 ⁵	¹²⁶ Cd	1.331 x 10 ⁶	¹⁶⁷ Eu	7.431 x 10 ²	¹¹⁷ In	4.753 x 10 ²	⁹⁹ Mo	2.838 x 10 ⁵
^{117m} Ag	1.380 x 10 ⁵	^{126m} Cd	1.378 x 10 ⁶	¹⁶⁸ Eu	2.686 x 10 ³	^{117m} In	6.445 x 10 ²	²⁴ Na	7.640 x 10 ²
¹¹⁹ Ag	2.132 x 10 ⁵	¹²⁷ Cd	6.879 x 10 ⁴	¹⁶⁹ Eu	8.784 x 10 ³	¹¹⁹ In	6.718 x 10 ⁴	¹⁰¹ Nb	8.317 x 10 ⁷
¹²¹ Ag	8.580 x 10 ⁴	¹²⁸ Cd	3.055 x 10 ⁴	¹⁶¹ Eu	1.955 x 10 ³	^{119m} In	5.764 x 10 ⁴	¹⁰³ Nb	3.699 x 10 ⁷
¹²² Ag	2.189 x 10 ⁴	¹²⁹ Cd	5.167 x 10 ³	¹⁶⁵ Eu	2.181 x 10 ⁰	¹²¹ In	2.471 x 10 ⁵	¹⁰⁴ Nb	1.359 x 10 ⁷
¹²⁶ Ag	2.355 x 10 ³	¹³⁰ Cd	1.359 x 10 ⁴	⁷² Ga	4.220 x 10 ⁻²	^{121m} In	6.493 x 10 ⁴	¹⁰⁶ Nb	3.571 x 10 ⁶
¹²⁸ Ag	8.993 x 10 ²	¹³¹ Cd	1.296 x 10 ³	⁷³ Ga	1.554 x 10 ²	¹²³ In	2.502 x 10 ⁶	¹⁰⁸ Nb	1.213 x 10 ⁶
^{128m} Ag	2.342 x 10 ¹	¹³² Cd	1.035 x 10 ²	⁷⁴ Ga	2.558 x 10 ⁴	^{123m} In	1.111 x 10 ⁶	¹⁰⁷ Nb	1.928 x 10 ⁵
²⁶ Al	6.827 x 10 ⁰	¹⁴¹ Ce	1.056 x 10 ²	⁷⁷ Ga	1.515 x 10 ⁶	¹²⁵ In	2.265 x 10 ⁶	¹⁰⁹ Nb	4.387 x 10 ²
^{26m} Al	3.982 x 10 ⁻⁹	¹⁴³ Ce	1.826 x 10 ⁵	⁷⁸ Ga	3.094 x 10 ⁵	^{126m} In	1.733 x 10 ⁵	¹¹¹ Nb	5.081
⁷⁶ As	2.036 x 10 ⁻²	¹⁴⁴ Ce	2.381 x 10 ³	⁷⁹ Ga	2.820 x 10 ⁵	¹²⁸ In	8.060 x 10 ⁵	^{93m} Nb	2.532
⁷⁷ As	5.028 x 10 ²	¹⁴⁶ Ce	6.120 x 10 ⁷	⁸⁰ Ga	3.690 x 10 ⁵	¹²⁷ In	4.514 x 10 ⁵	⁹⁴ Nb	1.217 x 10 ⁻⁸
⁷⁸ As	3.082 x 10 ³	¹⁴⁷ Ce	3.726 x 10 ⁷	⁸¹ Ga	1.963 x 10 ⁵	^{127m} In	4.530 x 10 ⁵	^{94m} Nb	6.170 x 10 ⁰
⁷⁹ As	6.080 x 10 ⁵	¹⁴⁸ Ce	1.307 x 10 ⁷	⁸² Ga	1.599 x 10 ⁴	^{128m} In	1.068 x 10 ⁶	⁹⁶ Nb	4.915 x 10 ⁻¹
⁸¹ As	3.421 x 10 ⁰	¹⁵¹ Ce	1.284 x 10 ⁶	⁸⁴ Ga	9.208 x 10 ²	¹²⁹ In	6.651 x 10 ⁵	^{96m} Nb	4.822 x 10 ⁰
⁸³ As	7.059 x 10 ⁰	¹⁵² Ce	2.203 x 10 ⁴	¹⁵² Gd	5.688 x 10 ⁻⁶	¹³⁰ In	1.242 x 10 ⁶	⁹⁸ Nb	8.107 x 10 ¹
⁸⁴ As	5.308 x 10 ⁰	¹⁵⁴ Ce	5.715 x 10 ¹	¹⁵⁶ Gd	4.507 x 10 ¹	¹³¹ In	4.098 x 10 ⁵	⁹⁷ Nb	1.348 x 10 ⁵
⁸⁵ As	3.470 x 10 ⁰	^{156m} Ce	1.550 x 10 ⁰	¹⁶¹ Gd	2.157 x 10 ³	¹³² In	1.110 x 10 ⁵	^{97m} Nb	1.165 x 10 ⁰
⁸⁶ As	1.909 x 10 ⁰	¹⁵⁷ Ce	4.308 x 10 ⁻²	¹⁶⁵ Gd	3.926 x 10 ¹	¹³³ In	6.630 x 10 ³	^{98m} Nb	9.739 x 10 ⁷
⁸⁷ As	1.080 x 10 ⁰	⁷² Co	1.500 x 10 ¹	⁷⁶ Ge	2.827 x 10 ³	¹³⁴ In	1.181 x 10 ²	^{99m} Nb	9.145 x 10 ⁴
⁸⁸ As	4.406 x 10 ⁴	⁷³ Co	1.573 x 10 ⁰	^{76m} Ge	1.058 x 10 ³	⁸¹ Kr	3.032 x 10 ⁻¹²	⁹⁹ Nb	9.776 x 10 ⁷
⁸⁹ As	3.468 x 10 ³	⁷⁵ Co	1.623 x 10 ⁻¹	⁷⁷ Ge	9.492 x 10 ²	^{81m} Kr	1.494 x 10 ⁻²	^{99m} Nb	2.463 x 10 ⁶
^{136m} Ba	3.368 x 10 ⁻²	¹³² Cs	5.413 x 10 ⁻⁶	^{77m} Ge	1.413 x 10 ⁵	^{83m} Kr	2.194 x 10 ⁴	¹⁴⁷ Nd	8.173 x 10 ³
¹³⁶ Ba	5.902 x 10 ⁰	¹³⁴ Cs	2.618 x 10 ⁻³	⁷⁸ Ge	4.240 x 10 ⁴	⁸⁵ Kr	2.497 x 10 ⁻¹	¹⁴⁹ Nd	1.556 x 10 ⁶
¹⁴⁰ Ba	5.889 x 10 ⁴	^{134m} Cs	2.924 x 10 ¹	⁷⁹ Ge	7.297 x 10 ⁵	^{86m} Kr	6.555 x 10 ⁵	¹⁵¹ Nd	4.239 x 10 ⁶
¹⁴¹ Ba	4.486 x 10 ⁷	¹³⁶ Cs	2.101 x 10 ⁻⁷	⁸¹ Ge	2.421 x 10 ⁰	⁸⁷ Kr	5.628 x 10 ⁶	¹⁵³ Nd	2.503 x 10 ⁶
¹⁴² Ba	6.380 x 10 ⁷	^{136m} Cs	2.048 x 10 ³	⁸³ Ge	1.645 x 10 ⁶	⁸⁸ Kr	3.930 x 10 ⁶	¹⁵⁵ Nd	2.994 x 10 ⁵
¹⁴³ Ba	8.844 x 10 ⁷	¹³⁸ Cs	7.438 x 10 ¹	⁸⁴ Ge	3.207 x 10 ⁵	⁸⁹ Kr	7.506 x 10 ⁷	¹⁵⁶ Nd	5.953 x 10 ⁴
¹⁴⁴ Ba	7.104 x 10 ⁷	¹³⁷ Cs	5.090 x 10 ¹	⁸⁶ Ge	1.078 x 10 ⁵	⁹⁰ Kr	7.689 x 10 ⁷	¹⁵⁷ Nd	1.004 x 10 ⁴
¹⁴⁶ Ba	3.327 x 10 ⁷	^{138m} Cs	1.271 x 10 ⁷	⁸⁸ Ge	1.908 x 10 ⁴	⁹¹ Kr	5.673 x 10 ⁷	¹⁵⁸ Nd	1.126 x 10 ³

Table E-4. GTA Fission and Activation Product Inventory 2 GW, 1,000 Second Operation
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Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
¹⁰⁹ Be	4.189 x 10 ⁻⁶	¹⁴⁰ Cs	9.670 x 10 ⁷	² H	5.204 x 10 ⁻¹	⁸⁴ Kr	3.803 x 10 ⁶	⁷² Ni	4.941 x 10 ²
⁸⁰ Br	3.132 x 10 ⁰	¹⁴¹ Cs	7.391 x 10 ⁷	¹⁶⁶ Ho	6.969 x 10 ⁻⁴	⁸⁶ Kr	1.711 x 10 ⁶	⁷³ Ni	2.533 x 10 ²
^{80m} Br	2.040 x 10 ⁻¹	¹⁴² Cs	4.752 x 10 ⁷	^{166m} Ho	9.116 x 10 ⁻¹⁰	⁸⁸ Kr	2.799 x 10 ⁴	⁷⁵ Ni	1.670 x 10 ²
⁸¹ Br	9.024 x 10 ⁰	¹⁴³ Cs	2.545 x 10 ⁷	¹²⁶ I	7.310 x 10 ¹	⁸⁷ Kr	6.832 x 10 ²	⁷⁷ Ni	7.567 x 10 ⁰
⁸² Br	1.045 x 10 ⁻³	¹⁴⁴ Cs	5.314 x 10 ⁶	¹²⁸ I	4.057 x 10 ⁻⁶	⁸⁸ Kr	7.145 x 10 ¹	⁷⁹ Ni	8.491 x 10 ⁻¹
⁸³ Br	4.433 x 10 ⁴	¹⁴⁵ Cs	1.204 x 10 ⁶	¹³⁰ I	4.981 x 10 ¹	¹⁴⁰ La	6.235 x 10 ²	^{230m} Np	7.221 x 10 ⁻¹⁰
⁸⁴ Br	3.869 x 10 ⁶	¹⁴⁶ Cs	1.359 x 10 ⁵	^{130m} I	9.523 x 10 ²	¹⁴¹ La	1.209 x 10 ⁶	²³⁷ Np	2.025 x 10 ⁻¹⁰
⁸⁵ Br	1.989 x 10 ⁷	¹⁴⁷ Cs	9.924 x 10 ³	¹³¹ I	1.655 x 10 ³	¹⁴² La	4.671 x 10 ⁶	²³⁸ Np	1.334 x 10 ⁻⁴
⁸⁷ Br	3.627 x 10 ⁷	⁶⁶ Cu	7.632 x 10 ⁻³	¹³² I	3.296 x 10 ⁴	¹⁴³ La	5.435 x 10 ⁷	²³⁹ Np	1.722 x 10 ⁻³
⁸⁸ Br	4.182 x 10 ⁷	⁶⁷ Cu	1.660 x 10 ⁻⁶	¹³³ I	2.379 x 10 ⁵	¹⁴⁴ La	8.860 x 10 ⁷	²⁴⁰ Np	6.385 x 10 ⁰
⁸⁹ Br	3.158 x 10 ⁷	⁷² Cu	1.058 x 10 ³	^{133m} I	2.158 x 10 ⁶	¹⁴⁵ La	6.154 x 10 ⁷	^{240m} Np	1.070 x 10 ¹
⁹⁰ Br	2.128 x 10 ⁷	⁷³ Cu	1.906 x 10 ³	¹³⁴ I	5.441 x 10 ⁶	¹⁴⁷ La	1.786 x 10 ⁷	²⁴¹ Np	1.582 x 10 ⁻⁴
⁹¹ Br	6.594 x 10 ⁶	⁷⁶ Cu	4.706 x 10 ³	^{134m} I	7.229 x 10 ⁶	¹⁴⁸ La	1.191 x 10 ⁶	²³² Pa	5.893 x 10 ⁻¹⁰
⁹² Br	3.173 x 10 ⁴	⁷⁷ Cu	1.967 x 10 ³	¹³⁶ I	2.973 x 10 ⁶	¹⁵¹ La	1.501 x 10 ⁴	²³⁴ Pa	3.337 x 10 ⁻⁹
⁹³ Br	7.884 x 10 ⁴	⁷⁸ Cu	7.459 x 10 ²	¹³⁷ I	5.453 x 10 ⁷	¹⁵² La	2.527 x 10 ¹	¹⁰⁷ Pd	1.252 x 10 ⁻⁶
⁹⁴ Br	5.475 x 10 ⁻³	⁷⁹ Cu	8.698 x 10 ¹	¹³⁸ I	2.772 x 10 ⁷	²⁷ Mg	2.019 x 10 ⁵	^{107m} Pd	1.305 x 10 ⁻²
¹⁰⁰ Pd	6.438 x 10 ⁻³	⁸⁴ Rb	2.956 x 10 ⁷	¹³⁸ Sb	9.965 x 10 ¹	⁸⁴ Sr	9.844 x 10 ⁷	¹³³ Xe	2.274 x 10 ¹
^{100m} Pd	2.544 x 10 ⁵	⁸⁵ Rb	1.516 x 10 ⁷	⁷⁰ Se	7.153 x 10 ⁻⁵	⁸⁶ Sr	9.095 x 10 ⁷	^{133m} Xe	4.802 x 10 ²
¹¹¹ Pd	1.597 x 10 ⁵	⁸⁶ Rb	3.375 x 10 ⁶	^{70m} Se	4.637 x 10 ⁵	⁸⁷ Sr	3.229 x 10 ⁷	¹³⁶ Xe	2.258 x 10 ⁴
^{111m} Pd	1.257 x 10 ²	⁸⁷ Rb	6.099 x 10 ⁵	⁸¹ Se	1.522 x 10 ⁶	⁸⁸ Sr	1.175 x 10 ⁷	^{136m} Xe	1.645 x 10 ⁶
¹¹² Pd	2.996 x 10 ⁻³	⁸⁸ Rb	8.820 x 10 ⁴	^{81m} Se	2.093 x 10 ⁴	⁸⁹ Sr	2.582 x 10 ⁶	¹³⁷ Xe	9.362 x 10 ⁷
¹¹³ Pd	3.088 x 10 ⁵	⁸⁹ Rb	6.807 x 10 ³	⁸³ Se	1.328 x 10 ⁶	¹⁶⁰ Tb	1.792 x 10 ⁻⁴	¹³⁸ Xe	5.816 x 10 ⁷
¹¹⁶ Pd	2.542 x 10 ⁵	^{103m} Rh	8.560 x 10 ²	^{83m} Se	5.588 x 10 ⁶	¹⁶¹ Tb	1.831 x 10 ⁰	^{138m} Xe	8.500 x 10 ⁷
¹¹⁷ Pd	2.648 x 10 ⁵	¹⁰⁴ Rh	1.421 x 10 ⁰	⁸⁴ Se	1.608 x 10 ⁷	¹⁶² Tb	6.718 x 10 ¹	¹⁴⁰ Xe	5.939 x 10 ⁷
¹¹⁸ Pd	5.793 x 10 ⁴	^{104m} Rh	5.986 x 10 ⁻¹	⁸⁶ Se	1.054 x 10 ⁷	¹⁰¹ Tc	1.611 x 10 ⁷	¹⁴¹ Xe	1.969 x 10 ⁷
¹²¹ Pd	5.015 x 10 ³	¹⁰⁶ Rh	1.104 x 10 ³	^{86m} Se	7.694 x 10 ⁶	¹⁰² Tc	5.273 x 10 ⁷	¹⁴² Xe	6.396 x 10 ⁶
¹²³ Pd	2.665 x 10 ²	^{106m} Rh	9.076 x 10 ⁴	⁸⁷ Se	1.637 x 10 ⁷	¹⁰⁴ Tc	1.286 x 10 ⁷	¹⁴³ Xe	8.719 x 10 ⁵
¹²⁶ Pd	6.544 x 10 ⁻¹	¹⁰⁸ Rh	5.986 x 10 ¹	⁸⁸ Se	5.983 x 10 ⁶	¹⁰⁶ Tc	1.225 x 10 ⁷	¹⁴⁴ Xe	1.101 x 10 ⁵
¹⁴⁶ Pm	1.757 x 10 ⁻¹⁰	¹⁰⁷ Rh	8.847 x 10 ⁵	⁸⁹ Se	1.555 x 10 ⁶	¹⁰⁸ Tc	6.969 x 10 ⁶	¹⁴⁵ Xe	2.505 x 10 ³
¹⁴⁷ Pm	2.439 x 10 ⁻²	¹⁰⁹ Rh	7.482 x 10 ⁵	⁹⁰ Se	5.387 x 10 ⁵	¹⁰⁷ Tc	3.170 x 10 ⁶	¹⁴⁶ Xe	2.328 x 10 ²
¹⁴⁸ Pm	1.273 x 10 ⁻¹	^{109m} Rh	3.741 x 10 ⁵	⁹¹ Se	5.390 x 10 ⁴	¹⁰⁹ Tc	4.212 x 10 ⁵	¹⁴⁷ Xe	4.098 x 10 ⁰
^{148m} Pm	2.435 x 10 ⁻³	¹¹¹ Rh	4.378 x 10 ⁵	⁹² Se	8.022 x 10 ²	¹¹¹ Tc	4.291 x 10 ⁴	¹⁰¹ Y	4.551 x 10 ⁶
¹⁴⁹ Pm	2.436 x 10 ³	¹¹² Rh	3.013 x 10 ⁵	¹⁵¹ Sm	1.478 x 10 ⁻³	¹¹² Tc	9.059 x 10 ²	¹⁰³ Y	8.954 x 10 ⁴
¹⁵⁰ Pm	6.196 x 10 ²	¹¹³ Rh	2.582 x 10 ⁵	¹⁵² Sm	6.143 x 10 ³	¹¹³ Tc	1.979 x 10 ²	¹⁰⁴ Y	4.265 x 10 ³
¹⁵¹ Pm	1.673 x 10 ⁴	¹¹⁵ Rh	9.618 x 10 ⁴	¹⁵⁶ Sm	2.291 x 10 ⁵	¹¹⁵ Tc	2.489 x 10 ¹	¹⁰⁶ Y	3.770 x 10 ²
¹⁵² Pm	2.232 x 10 ⁶	¹¹⁷ Rh	1.015 x 10 ⁵	¹⁵⁸ Sm	4.894 x 10 ³	¹¹⁷ Tc	1.936 x 10 ⁻¹	¹⁰⁷ Y	6.257 x 10 ⁻¹
¹⁵⁵ Pm	5.621 x 10 ⁵	¹¹⁹ Rh	7.231 x 10 ²	¹⁵⁷ Sm	9.208 x 10 ⁴	⁹⁹ Tc	2.023 x 10 ⁻⁶	⁹⁰ Y	1.439 x 10 ²
¹⁵⁶ Pm	1.941 x 10 ⁵	¹²¹ Rh	9.077 x 10 ⁰	^{158m} Sm	1.424 x 10 ⁴	^{99m} Tc	3.921 x 10 ⁻³	^{90m} Y	1.249 x 10 ¹
¹⁵⁷ Pm	6.816 x 10 ⁴	¹²³ Rh	8.700 x 10 ⁻²	¹⁵⁹ Sm	1.735 x 10 ⁴	^{123m} Te	1.660 x 10 ⁻⁷	⁹¹ Y	5.852 x 10 ¹
¹⁵⁸ Pm	1.855 x 10 ⁴	¹⁰³ Ru	8.895 x 10 ⁻³	¹⁶¹ Sm	6.947 x 10 ²	^{125m} Te	3.351 x 10 ⁻⁴	^{91m} Y	1.132 x 10 ⁵

Table E-4. GTA Fission and Activation Product Inventory 2 GW, 1,000 Second Operation
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Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)	Isotope	Inventory (Curies)
¹⁴² Pr	6.694 x 10 ⁻³	¹⁰⁷ Ru	2.883 x 10 ⁶	^{118m} Sn	7.514 x 10 ⁻¹	¹²⁹ Te	5.948 x 10 ⁴	⁹⁴ Y	4.245 x 10 ⁷
^{143m} Pr	2.790 x 10 ⁻¹	¹⁰⁸ Ru	7.376 x 10 ⁵	¹²¹ Sn	2.013 x 10 ³	^{129m} Te	5.284 x 10 ¹	⁹⁶ Y	6.901 x 10 ⁷
¹⁴³ Pr	3.861 x 10 ¹	¹¹¹ Ru	3.447 x 10 ⁵	^{121m} Sn	5.873 x 10 ⁻⁵	¹³¹ Te	4.018 x 10 ⁶	⁹⁷ Y	8.450 x 10 ⁷
¹⁴⁴ Pr	1.471 x 10 ³	¹¹² Ru	1.753 x 10 ⁵	¹²³ Sn	5.637 x 10 ⁰	^{131m} Te	2.421 x 10 ⁴	⁹⁸ Y	6.053 x 10 ⁷
^{144m} Pr	4.572 x 10 ²	¹¹³ Ru	9.481 x 10 ⁴	^{123m} Sn	7.256 x 10 ⁴	¹³² Te	1.438 x 10 ⁵	⁹⁹ Y	3.370 x 10 ⁷
¹⁴⁵ Pr	1.483 x 10 ⁶	¹¹⁵ Ru	8.187 x 10 ³	¹²⁴ Sn	2.155 x 10 ²	^{132m} Te	3.264 x 10 ⁷	⁷² Zn	4.795 x 10 ⁰
¹⁴⁷ Pr	1.973 x 10 ⁷	¹¹⁷ Ru	8.035 x 10 ²	¹²⁶ Sn	2.817 x 10 ⁵	^{133m} Te	9.196 x 10 ⁶	⁷³ Zn	4.048 x 10 ³
¹⁴⁸ Pr	1.776 x 10 ⁷	¹²² Sb	3.917 x 10 ⁻³	^{126m} Sn	2.655 x 10 ⁻⁴	¹³⁴ Te	2.714 x 10 ⁷	⁷⁴ Zn	2.295 x 10 ⁴
¹⁵¹ Pr	5.031 x 10 ⁶	^{123m} Sb	7.398 x 10 ⁻¹	¹²⁷ Sn	1.490 x 10 ⁵	¹³⁶ Te	5.506 x 10 ⁷	⁷⁷ Zn	6.254 x 10 ⁴
¹⁵² Pr	5.459 x 10 ⁵	¹²⁴ Sb	2.598 x 10 ⁻²	^{127m} Sn	7.921 x 10 ⁵	^{136m} Te	3.145 x 10 ⁷	⁷⁸ Zn	7.185 x 10 ⁴
¹⁵⁵ Pr	1.154 x 10 ⁴	^{124m} Sb	1.121 x 10 ²	¹²⁸ Sn	1.102 x 10 ⁶	¹³⁷ Te	7.064 x 10 ⁶	⁷⁹ Zn	2.772 x 10 ⁴
¹⁵⁶ Pr	8.618 x 10 ²	¹²⁵ Sb	1.355 x 10 ⁰	^{128m} Sn	2.947 x 10 ⁶	¹³⁸ Te	1.462 x 10 ⁶	⁸⁰ Zn	1.265 x 10 ⁴
¹⁵⁷ Pr	5.399 x 10 ¹	¹²⁶ Sb	1.051 x 10 ¹	^{129m} Sn	5.808 x 10 ⁶	^{138m} Te	2.179 x 10 ⁵	⁸¹ Zn	2.211 x 10 ³
¹⁵⁸ Pr	2.166 x 10 ⁰	^{126m} Sb	3.827 x 10 ³	¹³¹ Sn	1.642 x 10 ⁷	¹⁴⁰ Te	2.030 x 10 ⁴	⁸³ Zn	1.711 x 10 ¹
¹⁵⁹ Pr	3.599 x 10 ⁻²	¹²⁷ Sb	1.585 x 10 ³	¹³² Sn	9.916 x 10 ⁶	¹⁴¹ Te	7.038 x 10 ²	¹⁰¹ Zr	5.808 x 10 ⁷
²³⁸ Pu	5.442 x 10 ⁻⁷	¹²⁸ Sb	5.662 x 10 ³	¹³³ Sn	2.835 x 10 ⁶	¹⁴² Te	1.382 x 10 ¹	¹⁰² Zr	8.892 x 10 ⁶
²⁴⁰ Pu	1.603 x 10 ⁻⁸	¹²⁹ Sb	3.655 x 10 ⁵	¹³⁴ Sn	1.996 x 10 ⁵	²³¹ Th	4.533 x 10 ⁻⁴	¹⁰⁴ Zr	1.346 x 10 ⁶
²⁴¹ Pu	5.396 x 10 ⁻⁹	¹³⁰ Sb	9.151 x 10 ⁵	¹³⁵ Sn	2.080 x 10 ⁴	²³² Th	1.560 x 10 ⁻⁸	¹⁰⁶ Zr	1.729 x 10 ⁵
⁸⁶ Rb	5.349 x 10 ⁻¹	¹³¹ Sb	1.640 x 10 ⁷	¹³⁶ Sn	9.146 x 10 ²	²³⁴ Th	2.352 x 10 ⁻⁷	¹⁰⁸ Zr	4.149 x 10 ⁴
⁸⁸ Rb	9.233 x 10 ²	¹³² Sb	2.697 x 10 ⁷	¹⁰¹ Sr	4.960 x 10 ⁴	²³⁵ U	5.871 x 10 ⁻⁶	¹⁰⁷ Zr	1.992 x 10 ³
⁸⁷ Rb	1.371 x 10 ⁻⁶	^{132m} Sb	1.676 x 10 ⁷	¹⁰² Sr	8.061 x 10 ¹	²³⁴ U	8.850 x 10 ⁻⁶	¹⁰⁸ Zr	3.026 x 10 ⁻¹
⁸⁹ Rb	1.305 x 10 ⁶	¹³³ Sb	3.732 x 10 ⁷	¹⁰⁴ Sr	1.391 x 10 ⁰	²³⁶ U	6.028 x 10 ⁻²	⁹³ Zr	5.534
⁹⁰ Rb	3.359 x 10 ⁷	¹³⁴ Sb	4.517 x 10 ⁶	^{87m} Sr	1.089 x 10 ⁰	²³⁸ U	3.521 x 10 ⁻⁴	⁹⁵ Zr	5.167 x 10 ⁻¹
^{90m} Rb	7.542 x 10 ⁷	^{134m} Sb	4.317 x 10 ⁶	⁹⁰ Sr	2.414 x 10 ³	²³⁷ U	5.026 x 10 ¹	⁹⁷ Zr	1.110 x 10 ⁶
⁹¹ Rb	1.500 x 10 ⁷	¹³⁵ Sb	3.300 x 10 ⁶	⁹¹ Sr	5.281 x 10 ¹	^{238m} U	7.064 x 10 ⁻⁴	⁹⁸ Zr	9.664 x 10 ⁷
⁹² Rb	9.404 x 10 ⁷	¹³⁶ Sb	5.015 x 10 ⁵	⁹² Sr	1.792 x 10 ⁶	²⁴⁰ U	9.360 x 10 ⁵	⁹⁹ Zr	9.547 x 10 ⁷
^{92m} Rb	7.961 x 10 ⁷	¹³⁷ Sb	3.575 x 10 ⁴	⁹³ Sr	8.841 x 10 ⁶				
⁹³ Rb	5.902 x 10 ⁷	¹³⁸ Sb	2.226 x 10 ³			²⁴¹ U	7.443 x 10 ⁻⁴		

Table E-5. Total Fission Product Releases for PIPET and GTA Maximum Operating Scenarios

Isotope	Release (Ci)	
	PIPET	GTA
Br-88	1.255×10^{-1}	1.736×10^{-1}
Kr-88	8.645×10^3	1.25×10^{-6}
Rb-88	1.132×10^3	2.844×10^{-4}
Kr-91	1.927×10^2	1.304×10^{-2}
Rb-91	8.491×10^3	2.395×10^{-4}
Sr-91	1.561×10^4	2.544×10^{-6}
Y-91m	4.455×10^2	1.364×10^{-4}
Y-91	4.391×10^{-1}	1.394×10^{-1}
Sr-92	7.548×10^4	1.019×10^{-6}
Y-92	9.255×10^2	2.330×10^{-4}
Sr-95	6.994×10^4	1.412×10^{-6}
Y-95	1.198×10^6	7.076×10^{-6}
Zr-95	4.863×10^0	7.456×10^{-1}
Nb-95m	4.285×10^{-3}	6.234×10^{-2}
Nb-95	3.749×10^{-2}	1.126×10^{-2}
Zr-97	4.354×10^2	6.285×10^{-3}
Nb-97m	5.155×10^2	6.539×10^{-3}
Nb-97	8.050×10^1	1.779×10^{-3}
Mo-105	3.379×10^1	9.375×10^{-1}
Tc-105	1.556×10^2	1.500×10^{-3}
Ru-105	1.621×10^0	3.401×10^{-1}
Rh-105m	3.415×10^{-1}	8.202×10^0
Rh-105	1.450×10^{-3}	6.369×10^{-2}
Sn-132	7.370×10^{-2}	1.833×10^{-1}
Sb-132m	1.010×10^0	6.499×10^0
Sb-132	1.208×10^0	7.357×10^0
Te-132	3.390×10^{-1}	6.260×10^0
I-132	1.145×10^{-2}	2.796×10^{-1}
Sn-133	1.201×10^{-2}	2.790×10^{-2}
Sb-133	1.282×10^0	5.765×10^0
Te-133m	3.834×10^1	5.448×10^{-2}
Te-133	7.196×10^1	8.983×10^{-2}
I-133m	6.523×10^{-2}	4.298×10^{-2}
I-133	2.431×10^{-1}	6.119×10^0
Xe-133m	4.531×10^{-1}	6.621×10^0
Xe-133	3.846×10^{-1}	7.806×10^0
Sb-134	6.145×10^{-2}	5.724×10^{-2}
Te-134	9.332×10^1	1.232×10^{-3}
I-134m	1.358×10^0	7.999×10^0
I-134	5.223×10^0	1.230×10^{-2}
Te-135	5.511×10^0	9.016×10^0
I-135	1.139×10^0	1.262×10^{-1}
Xe-135m	4.273×10^3	4.950×10^{-4}
Xe-135	2.194×10^2	4.014×10^{-3}
Cs-135m	1.745×10^2	2.274×10^{-3}
I-138	9.213×10^{-2}	3.134×10^{-2}
Xe-138	2.348×10^6	2.564×10^{-6}
Cs-138m	2.972×10^4	1.494×10^{-6}
Cs-138	6.572×10^4	1.319×10^{-6}
Xe-140	2.080×10^3	2.439×10^{-3}
Cs-140	3.133×10^6	9.242×10^{-6}
Ba-140	1.299×10^2	1.151×10^{-3}
La-140	1.313×10^{-1}	2.561×10^0
Ba-142	1.876×10^2	1.904×10^{-3}
La-142	5.863×10^0	1.195×10^{-2}

Source: Young, 1992.

Table E-6. Fission Product Release Fractions for Elements

Release Category	Release Basis (diffusion)	Release Average (percent)	Grouped Elements
Nobles ^(a)	Xe, Kr	3.0	Xe, Kr
Halogens	I	1.0	I, Br
HR ^(b) non-Volatiles	Cs, Sr	13.0	Cs, Rb, Na, Cu, Sr, Ba, Mg, Be
LR ^(c) non-Volatiles	Zr, Nb, Mo, Tc, Te, Ba	1.6	Te, Se, Sb, Po, Ru, Rh, Pd, Nb, Mo, Tc, Zr, Ce, Th, Pa, U, Np, Pu, C, La, Al, Y, Ac, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Am, Sn, Ag, In, Ge, Ga, Gd, Zn, As, Si

Notes: (a) 100 percent of the activated hydrogen is assumed to be released.

(b) High Release.

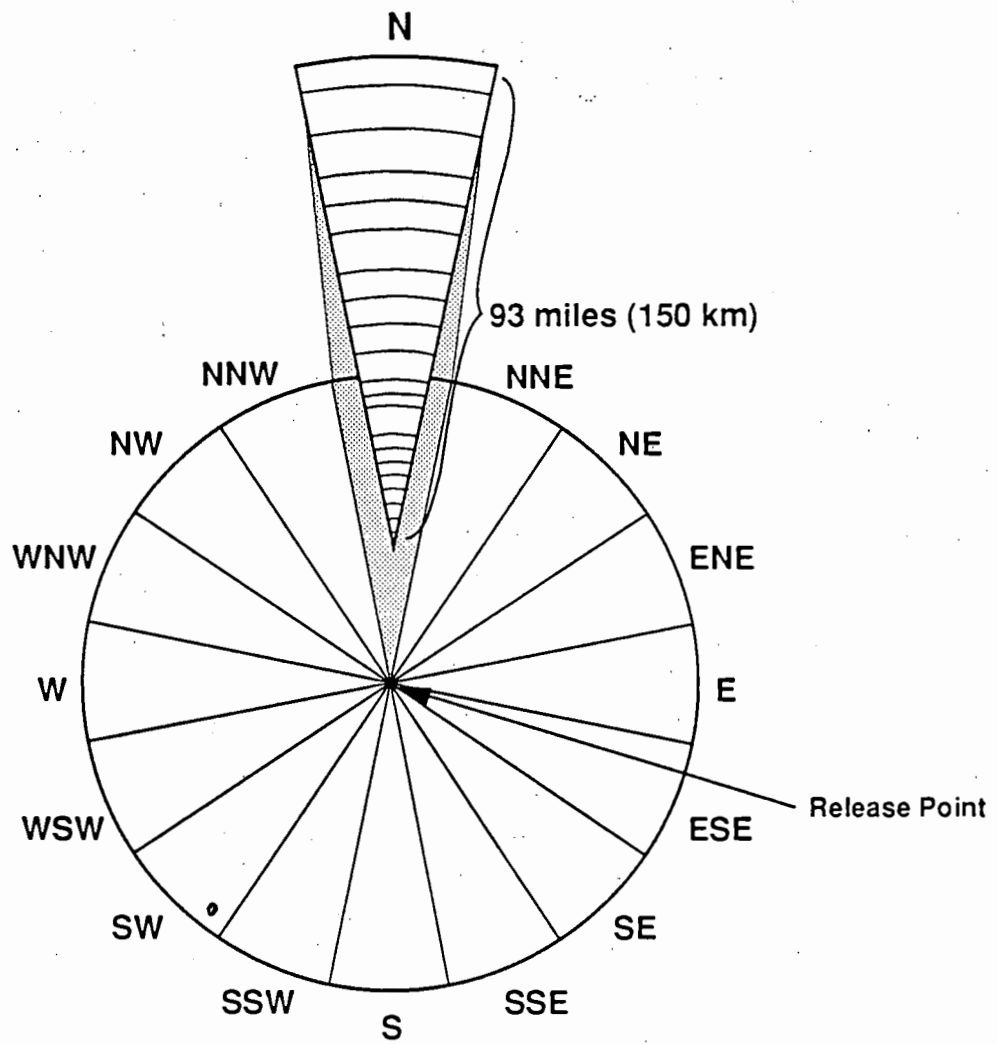
(c) Low Release.

release fractions used in the analyses below are 0.1 percent particulate releases and 0.5 percent volatile, halogen, and noble releases.

1.4 POPULATION SITE SPECIFIC DATA

Generally, site specific data are collected within a radius 80 kilometers downwind from the point of release. This has been standard practice in the past for evaluating radiological estimates for inclusion in impact analyses, and is set forth for evaluation of normal operations in 40 CFR Part 61, EPA NESHAP Policy. However, it was determined that for PBR propulsion technology evaluation, the distance downwind would be extended to 150 kilometers in order to include major population centers. This can be considered a reasonable and conservative approach where radiation doses may be as high as, or higher than, local background contributions. This is done with the understanding that Gaussian plume models such as MACCS are generally regarded as being unreliable for distances much past 100 kilometers. However, the estimates yielded by these codes are considered conservative even out to long distances from the release point. The additional exposure to people located beyond 150 kilometers would contribute very little to the total population dose and, therefore, is not considered.

For input into MACCS, population data are arranged onto a circular (polar) grid divided into 16 directional sectors and 26 radial distances measured from the source point to 150 kilometers distant (Figure E-1). Population doses estimated from this data assume that the population in each grid element is distributed evenly over the surface of the element.



MACCS Polar Grid

Figure E-1

Populations of major cities surrounding NTS are taken from 1990 census data provided by NTS (Leppert, 1992). Rural populations (including individual ranch sites) are taken from a 1989 U.S. EPA census (Thome, 1991). NTS crop, livestock, and water pathway data were extracted from the site radiological monitoring report (U.S. EPA, 1991) and input directly into the MACCS site file.

INEL population data for major cities and rural populations inside an 80 kilometer radius are taken from 1990 census data (Hardinger, 1992). Data from 80 to 150 kilometers were taken from 1980 census data (Chanin, 1992). At the time of writing, 1990 census data for areas surrounding INEL out to 150 kilometers were unavailable. The population data were input into MACCS in the same manner as described for the NTS data. Crop, livestock, and water pathway data for INEL were taken from a socioeconomic database (Hardinger, 1990) produced for the southeastern portion of the state of Idaho.

2.0 IMPACT ANALYSIS

2.1 OPERATIONAL SCENARIOS

Normal I

Normal I experiments include initial startup, zero-power, and low-power physics tests. Testing under these conditions may be performed without coolant flow and under normal operating conditions (non-accident) would not release radiological materials to the environment since test conditions would be significantly below full-power operation conditions. For this reason, Normal I experiments are not discussed or analyzed further.

Normal II

Normal II experiments are standard tests that would operate within the fuel design envelope, up to the core's rated full power (550 MW for PIPET and 2,000 MW for GTA). These experiments would release small amounts of the core inventory due to heat induced releases, properties of the fuel particles themselves, and cracking of a small number of fuel particles during each test. The amount of fission products released as a result of a Normal II operation would be as discussed in Section 1.3. PBR propulsion technology Normal II experiments would be performed using both GTA and PIPET cores.

Normal III

Normal III experiments, which would be performed using PIPET cores only, involve operations to determine fuel design margins, with the intent of quantifying actual design limits. These experiments would include over-power, reduced coolant flow, and extended duration testing. These tests

may involve full or partial fuel element failure where some fraction of the fuel in one or more fuel elements is released into the ETS. Current assessments of these experiments envision reduced run times (minimizing the inventory) with only partial failure of some of the fuel elements (minimizing the release). However, for purposes of performing conservative impact analyses, it is assumed that 100 percent of the core fission product inventory is released following a maximum case test. It is important to realize that the intent of these tests is to define the design margin, not to purposely fail the core. In actual testing no fuel element failure or release of significant portions of the core inventory to the ETS may occur.

2.2 IDENTIFICATION OF BOUNDING CASE SCENARIOS

Release Mechanisms

Source terms pertaining to Normal II and III operations are emitted in multiple plume segments. Normal II operations are simulated with two distinct plume segments. The first occurs during the course of a GTA or PIPET operation and consists of nominal diffusion driven and failed fuel fission product release, specified in Tables E-5 and E-6. The second Normal II plume segment releases volatile isotopes trapped by the absorber-beds during operation after they have decayed to safe levels. The time following operation after which the volatiles are released is assumed to be 1 day.

A third plume segment is used to model PIPET Normal III operations, in addition to the two previously mentioned plumes. This plume segment occurs at the end of the experiment, in which the remaining PIPET core inventory (100 percent) is assumed to enter the ETS over a small time interval of a few seconds and is subsequently emitted in accordance with ETS retention efficiencies.

Bounding Case Scenarios

A GTA core would undergo no more than 2.0 TJ total usage, which can be represented by a single maximum case test run of 2,000 MW for 1,000 seconds. Such a maximum case test would result in the highest total core inventory, since at the immediate conclusion of such an operation the maximum possible amount of all fission products would be present, with no time for decay of short-lived isotopes. Thus, the inventory present in a GTA core at the conclusion of a maximum case test run would represent the largest fission product inventory for evaluation. This inventory (Table E-4) is used for determination of the source term for the bounding case GTA Normal II operational impact. For isotopes in which specific release fractions have been established, this calculated value will be used (see Table E-5). Release amounts for the remaining inventory are estimated using the criteria established in Table E-6. Since Normal III operations would be conducted for PIPET only no analysis of this case is performed for GTA.

Each PIPET core can undergo a series of tests, up to the maximum lifetime usage of 1.375 TJ. Each test in this series can be separated by a week or more of post-test decay time before another operation is initiated. With each consecutive operation the long-lived fission product inventory of the core would increase, since these long-lived isotopes would not decay significantly between test runs, and may in fact increase due to decay of shorter-lived precursor isotopes. For modeling purposes, this is represented by five maximum case test operations (550 MW for 500 seconds). The core inventory resulting from the test series is calculated by allowing 1 week of decay time between test operations (this is quite conservative, since in reality the time between tests is expected to be much longer). The case of the core inventory immediately following the fifth test run would thus represent the maximum for all fission product isotopes, including long-lived species. This core inventory has been selected as the bounding case for the PIPET Normal II and Normal III analysis. As for GTA, Normal II PIPET inventory releases would be as shown in Table E-5 or calculated using Table E-6 criteria. For PIPET Normal III operations, the entire inventory is assumed to be released into the ETS.

The maximum case yearly operational impact is also assessed. The bounding case for this analysis is found by assuming testing of two PIPET cores, each operating 5 times at 550 MW for 500 seconds, and two GTA cores, each operating once at 2,000 MW for 1,000 seconds (see Section 1.3). In determining the contribution to annual dosage provided by the two PIPET cores, the final test of one of the cores is considered to be a Normal III experiment, the remaining nine tests are considered to be Normal II. The reported dose is the sum of the nine Normal II operations, and the one Normal III operation for two PIPET cores, and two Normal II GTA operations.

Impacts due to the entire PBR propulsion technology development and validation are based upon the cumulative effect of a 10-year test program duration. This would consist of five PIPET and one GTA Normal II operations each year, with a total of four PIPET Normal III operations during the 10-year period replacing four of the PIPET Normal II tests.

2.3 IMPACT ASSESSMENT

Impacts of Normal II and Normal III operations are provided based upon results of analysis for bounding case scenarios using the MACCS computer code. Meteorological conditions are assumed to correspond to the model conditions presented in Table E-1 for both SMTS and CTF, since pre-test forecasting and analysis would preclude conditions which may produce impacts greater than those presented here.

Results are presented for a single test run of each bounding case operational scenario, the maximum yearly impact, and the PBR propulsion technology

assessment lifetime, which is assumed to be ten years. Impacts are presented at the facility boundary (the nearest NTS/INEL boundary in the selected wind direction), the MEI, and the total population dosage. The radiological doses presented in these analyses are expressed as the sum of the external doses received from cloudshine and groundshine and the internal doses received from inhalation during plume passage and later resuspension inhalation, integrated over a 50-year period. Population doses also include the dose from ingestion of contaminated food and water. Virtually all the committed dose would be received in the first year following the radiological release.

Normal II Impacts

Tables E-7 and E-8 list the MEI, and population dose, respectively, for both PIPET and GTA Normal II operations. Both site boundary and peak doses are listed for comparison.

Table E-7. Normal II Operation Plume Center-Line MEI

Core (mrem/yr)	Site	Site Boundary		Peak		Annual Natural Radiation
		Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
PIPET	NTS	0.00066	39	0.0046	210	422
PIPET	INEL	0.00050	15	0.010	135	441
GTA	NTS	0.0090	39	0.011	190	422
GTA	INEL	0.012	15	0.028	18	441

PIPET. The dose at the NTS boundary following a single bounding case PIPET Normal II operation at SMTS is approximately 0.00066 mrem. The MEI occurs at approximately 210 kilometers with a magnitude of 0.0046 mrem. The dose at the INEL boundary following a single PIPET Normal II operation at CTF is approximately 0.00050 mrem. The MEI at INEL occurs at approximately 135 kilometers with a magnitude of 0.01 mrem.

GTA. The dose at the NTS boundary following a single GTA Normal II operation at SMTS is approximately 0.009 mrem. The MEI occurs at approximately 190 kilometers with a magnitude of 0.011 mrem. The dose at the INEL boundary following a single GTA Normal II operation at CTF is approximately 0.011 mrem. The MEI at INEL occurs at approximately 18 kilometers with a magnitude of 0.028 mrem.

The major differences between the magnitude of the INEL and NTS doses are caused by the differences in the selected inversion layer height as

Table E-8. Normal II Operation Population Dose

Core/Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose (Person-mrem)	Total Pop. Dose (Person-mrem)	Average Individual Dose (mrem)	Latent Cancer Fatalities	Genetic Disorders
PIPET/NTS	NNE	917	2.0	1,072,718	271.0	273.0	2.4×10^{-3}	2.2×10^{-4}	7.1×10^{-6}
PIPET/INEL	N	5,846	11.0	272,082	1,368.0	1,379.0	6.9×10^{-3}	1.1×10^{-3}	3.6×10^{-4}
GTA/NTS	NNE	917	5.1	1,072,718	209	214.0	2.0×10^{-4}	1.7×10^{-4}	5.6×10^{-6}
GTA/INEL	N	5,846	31.8	272,082	1,488	1,520.0	1.1×10^{-2}	1.2×10^{-3}	4.0×10^{-4}

evaluated at each site (1.5 kilometers at INEL and 2.0 kilometers at NTS). The maximum population dose for a single PIPET Normal II operation (fifth of a series) may result in the projection of up to 0.00022 additional cancer fatalities and 7.1×10^{-6} additional genetic disorders at NTS; and 0.0011 additional cancer fatalities and 0.00036 additional genetic disorders at INEL. For GTA, the maximum population dose may result in the projection of up to 0.0017 additional cancer fatalities and 5.6×10^{-6} additional genetic disorders at NTS, and up to 0.0012 additional cancer fatalities and 0.0004 additional genetic disorders at INEL. These results are in addition to the normally expected occurrences of these effects.

Normal III Impacts

Tables E-9 and E-10 list the MEI and population doses, respectively, for the PIPET Normal III operation. Both site boundary and peak doses are listed for comparison.

Table E-9. PIPET Normal III Operation Plume Center-Line MEI

Site	Site Boundary		Peak		Annual Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	0.13	39	0.53	190	422
INEL	0.06	15	1.2	125	441

The dose at the NTS boundary following a PIPET Normal III operation at SMTS would be approximately 0.13 mrem. The MEI would occur at approximately 190 kilometers with a magnitude of 0.53 mrem. The dose at the INEL boundary following a PIPET Normal III operation at CTF is approximately 0.06 mrem. The MEI would occur at approximately 125 kilometers with a magnitude of 1.2 mrem. Many of the differences between INEL and NTS results discussed for Normal II operations also apply for Normal III operations.

Population doses for a PIPET Normal III operation may result in the projection of approximately 0.02 additional cancer fatalities and 0.006 additional genetic disorders at NTS, and approximately 0.09 additional cancer fatalities and 0.03 additional genetic disorders at INEL.

Maximum Annual Operations

Tables E-11 and E-12 list the MEI and population doses, respectively, for the maximum yearly total release. The dose at the NTS boundary following the

Table E-10. PIPET Normal III Operation Population Dose

Core/Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose (Person-mrem)	Total Pop. Dose (Person-mrem)	Average Individual Dose (mrem)	Latent Cancer Fatalities	Genetic Disorders
NTS	NNE	917	86.0	1,072,718	24,600.0	24,686.0	1.2×10^{-1}	2.0×10^{-2}	6.4×10^{-3}
INEL	N	5,846	1,820.0	272,082	116,180.0	118,000.0	7.4×10^{-1}	9.3×10^{-2}	3.1×10^{-2}

Table E-11. Maximum Yearly Release Plume Center-Line MEI

Site	Site Boundary		Peak		Annual Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	0.16	39	0.60	195	422
INEL	0.10	15	1.35	125	441

maximum yearly release from SMTS would be approximately 0.16 mrem. The MEI would occur at approximately 195 kilometers with a magnitude of 0.6 mrem. The dose at the INEL boundary following the maximum yearly release at CTF would be approximately 0.10 mrem. The MEI at INEL would occur at approximately 125 kilometers with a magnitude of 1.35 mrem. These values are well below the NESHAP standard of 10 mrem.

Population doses for the maximum yearly release may result in the projection of approximately 0.02 additional cancer fatalities and 0.007 additional genetic disorders at NTS, and the projection of approximately 0.1 additional cancer fatalities and 0.04 additional genetic disorders at INEL.

PBR Propulsion Technology Development and Validation Impacts

During the 10-year lifetime of the PBR propulsion technology development and validation, impacts from each year would accumulate and collectively produce the total program-related dose. An average year is considered to consist of five PIPET Normal II Operations, and one GTA Normal II operation. During the 10-year test period a total of four PIPET Normal III operations will occur which will replace four of the PIPET Normal II tests.

Tables E-13 and E-14 present the cumulative lifetime impacts from the proposed PBR propulsion technology development program. Both MEI and population doses are listed for comparison.

The dose at the NTS boundary for PBR propulsion technology assessment releases from SMTS would be approximately 0.64 mrem. The MEI would occur at approximately 190 kilometers with a magnitude of 2.5 mrem. The dose at the INEL boundary for PBR propulsion technology assessment releases at CTF would be approximately 0.06 mrem. The MEI at INEL would occur at approximately 125 kilometers with a magnitude of 5.6 mrem.

Population doses for the lifetime of PBR propulsion technology assessment releases may result in the projection of approximately 0.09 additional cancer fatalities and 0.03 additional genetic disorders at NTS, and the projection of approximately 0.44 additional cancer fatalities and 0.14 additional genetic disorders at INEL.

Table E-12. Maximum Yearly Release 50-Year Population Dose

Core/Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose (Person-mrem)	Total Pop. Dose (Person-mrem)	Average Individual Dose (mrem)	Latent Cancer Fatalities	Genetic Disorders
NTS	NNE	917	114	1,072,718	27,457	27,571	0.15	0.022	0.007
INEL	N	5,846	1,983	272,082	131,468	133,451	0.82	0.105	0.035

Table E-13. Total SNTP Test Program Cumulative Center-Line MEI

Site	Site Boundary		Peak		10-Year Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	0.64	39	2.5	190	4220
INEL	0.06	15	5.6	125	4410

2.4 ACCIDENT SCENARIOS

2.4.1 Severe Accident Hazards Analysis

2.4.1.1 Summary. As part of the preparation of this analysis, the project team reviewed the entire evolution of the project to estimate the maximum possible consequences resulting from hypothetical severe accidents, regardless of their probability. In most cases, a mechanistic scenario was postulated that would produce a particular source term that could impact the environment or the health and safety of workers and the public. In one case, the source term was taken as the maximum theoretically possible, i.e., complete vaporization of a core containing the maximum possible fission-product inventory, and its release directly into the atmosphere. Current calculations indicate that no mechanism exists that could rupture both the primary and secondary confinement boundaries to allow such a direct unmitigated release, except through deliberate malevolent actions. Nevertheless, this Level 1 Source Term provides an upper bound on safety impacts. The value of such an unlikely assumption is that it ensures that all credible accidents will have consequences that are much less severe.

The population and regions at risk during severe accidents were divided into three separate groups by location: OSN - on-station personnel (within the facility perimeter fence); OST - on-site (e.g., NTS, INEL) but outside the facility fence; and P - members of the public situated off site. Five levels of source term severity were distinguished, depending on where and when the accident occurred during the facility life-cycle. These source terms then provided the input to the accident consequences calculations of radiation doses and health effects.

2.4.1.2 Introduction. In the preparation of this analysis, the project team systematically reviewed all these aspects of the project life cycle in an attempt to ensure that no potential hazards had been overlooked. Although this review resulted in both qualitative and quantitative estimates, it did not perform detailed analyses of all situations. More specific and thorough

Table E-14. Total SNTP Test Program Release 50-Year Population Dose

Core/Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose (Person-mrem)	Total Pop. Dose (Person-mrem)	Average Individual Dose (mrem)	Latent Cancer Fatalities	Genetic Disorders
NTS	NNE	917	487	1,072,718	112,956	113,442	0.64	0.09	0.03
INEL	N	5,846	8,104	272,082	542,528	550,634	3.38	0.44	0.14

investigations will be performed for the Safety Analysis Reports required before construction or operations can be approved by the appropriate regulatory agencies. This hazards "walk-through" presents conservative bounding results that can be used to compare the risks of the proposed project to other risks that the public normally accepts in the conduct of its economic, social, and political affairs.

All types of hazards were considered including toxic emissions, fires and explosions, and releases of radioactivity. For this facility, radiological hazards generally dominate the potential impact of the project during both normal operations and potential accidents.

The process of analyzing the potential radiological consequences of a severe accident begins with the definition of a "source term". The particular nuclides (e.g., ^{131}I , ^{133}Xe), amounts (in curies), chemistry and morphology (solid, respirable particulate, gas, etc.), half-life, and biological toxicity of the material released to the environment defines the radiological source term. Calculated core inventories for PIPET and GTA cores are shown in Tables E-3 and E-4. These inventories were calculated using ORIGEN2 in accordance with the parameters detailed in Section 1.3. Analysis of these cores led to the description of five distinct source terms that might occur in particular accidents. These source terms are defined in Table E-15.

Table E-15. EIS Source Term Levels

Level 1 Source Term:	all core vaporized coincident with the highest fission-product inventory; direct release to atmosphere without any mitigation.
Level 2 Source Term:	all core vaporized coincident with the highest fission-product inventory; release through ETS with failure of single most critical component and failure of confinement system.
Level 3 Source Term:	all core melts; source term from volatiles only (iodine, cesium, noble gases, etc.); release through ETS with failure of single most critical component and failure of the confinement system.
Level 4 Source Term:	accidental criticality leading to vaporization of core with no prior fission product inventory; release directly into atmosphere.
Level 5 Source Term:	cold core (i.e., no melting or vaporization) fragmented and dispersed by means of an external event (e.g., a hydrogen detonation); release directly into atmosphere.

All the potential accident scenarios are bounded or encompassed by these five sources. These source terms are then further analyzed by calculating their release to the environment, their transport based on release characteristics (velocity, temperature, composition) and meteorological

conditions (wind speed and direction, inversion layer presence and altitude, etc.), and the resulting biological doses based on deposition calculations, hypothetical location of maximally exposed individual, and population location and density. The integration of the source term with the conditions prevailing at the time of the accident and the transport, dispersal and deposition of the radionuclides determines the level of severity of the accident. Table E-5 presents specific release quantities for select radionuclides, which together account for approximately 75 percent of the total release. Calculation of releases for the balance of the core inventories are calculated using the release fraction information found in Table E-6 and the core inventories found in Tables E-3 and E-4.

Three accident consequence levels were chosen for analysis, since they encompass the most severe hypothetical accidents. A detailed discussion of the consequences are summarized in Table E-16 and the following discussion.

A Consequence I accident assumes Source Term Level 1 under worst-case assumptions for all other initial and boundary conditions (e.g., no credit taken for agglomeration, condensation or scavenging processes, maximum possible fission product inventory, GTA facility, etc.).

There are two Consequence II accidents, both of which employ Source Term Level 2. The accidents are assumed to occur following the maximum GTA operational cycle. The ETS is intact except for the assumed failure of the eight absorber bed stages. Two different failure times are considered: early, in which the prevailing weather conditions satisfy the normal operating safety constraints; and late, 10 hours after the run when the weather can no longer be presumed to be favorable. In the latter case, the worst-case weather is assumed to prevail: 300 meter inversion layer base, 1.0 meter per second wind blowing directly toward the nearest maximum population center (Las Vegas at NTS and Idaho Falls at INEL). The Level 3 Source Term is not calculated separately, since its consequences are less than Level 2 for these accident scenarios.

A Consequence III accident is assumed to occur during low-power testing if an inadvertent criticality occurs before the confinement system is in place. Although highly unlikely, some of the core could be vaporized and be released directly into the atmosphere. The same consequences can be considered to be bounding for any accidental criticality that occurs outside the confinement (e.g., during handling or storage) when the fission product inventory is very low. This accident would involve a Level 4 Source Term. The Level 5 Source Term is considered to lead to much more benign consequences than the previous accidents; therefore, it was not analyzed separately.

Table E-16. Accident Consequence Levels

Consequence Level I: The worst-case hypothetical accident in which the Level 1 Source Term is released to the atmosphere without mitigation.

Consequence Level II: The worst-case hypothetical accident considered to be credible without requiring extremely improbable external events or deliberate malevolent actions. The system is assumed vulnerable to the failure of the single most critical safety component. Source Term Level 2 is employed. Two Consequence II cases are distinguished, depending on whether the release occurs early or late in the accident.

Consequence Level III: This accident involves the complete vaporization of the core with little or no inventory of fission products at the time of the accident. This can occur early in the facility life cycle (during zero- or low-power testing), or late after the fission products have substantially decayed. A Level 4 Source Term applies.

Following is a brief overview of the hazards "walk-through" for various stages of project development and facility operations.

On-Station Handling and Storage Prior to Testing

A key concern in handling and storing test articles prior to testing is the possibility of accidental criticality. With proper design and engineering, the potential for accidental criticality can be discounted, thereby limiting the source term to Level 5. However, even if such an event were to occur, the source term would be less than Level 4, resulting in an accident of severity less than Consequence III.

In the absence of inadvertent criticality, a potential hazard arises from the energetic dispersal of uranium and/or beryllium due to a hydrogen detonation. However, the beryllium would not be hazardous unless burned or aerosolized; the heat flux from a hydrogen deflagration or detonation is insufficient to ignite or aerosolize the beryllium even if it were directly exposed to the flame. Inside the reactor vessel, there is no explosion hazard capable of releasing the beryllium. Fragmentation due to detonation-produced loads would limit the contamination and biological hazards to a very localized region around the facility.

Very unlikely external events can be postulated as accident initiators. These include airplane crashes into the facility, strong earthquakes, lightning strikes, terrorist attacks, or hydrogen detonations. In order to present an off-site threat to the public or the environment, radionuclides would have to be lofted into the air and subsequently fall out in populated areas.

In all cases, the consequences of non-deliberate events would involve source terms no worse than Level 5. Only in the case of deliberate sabotage could the source approach Level 4. The consequences of all such accidents are bounded by the Consequence III accident described in Section 2.4.2.

Low Inventory Testing

Low-inventory testing would not be initiated until the full Coolant Supply System (CSS) and Effluent Treatment System (ETS) were in place and operational. Although the fission product inventory could exceed the Level 4 Source Term, it would be less than Level 2. The Late-Time Accident Consequence II "Late" calculation (Section 2.4.3) would be bounding in the unlikely event of a severe accident, since no controls on the prevailing weather would apply, nor would sheltering or evacuation requirements be in place.

Power Testing

Credible reactor accident scenarios include (1) loss of flow while at high power; (2) reactivity addition accidents such as cold hydrogen flood while critical, or inadvertent control rod or safety rod movement; and (3) loss of cooling during post-operation cooldown (i.e., decay heat removal). The first two scenarios are calculated to lead to immediate ejection of the fuel as vapor, terminating the power excursion with less than 100 MJ or 300 MJ respectively of additional fission yield produced in the excursion. The excursion yield is thus 0.0036 percent of the yield from a normal series of operations upon which the worst-case accident is based (i.e., Level 1 source term).

Normal safety precautions would apply during all power testing, including protection of on-station workers, and operations constrained to coincide with favorable weather patterns, i.e., when wind direction and inversion layers are such that the dispersal of fission products is towards the least populated areas.

For potential consequences to on-site (OST) and off-site (P) personnel, source term Levels 1, 2 or 3 would be bounding for design basis accidents (DBAs) or severe accidents (beyond DBA). The approach chosen assumes that the DBA is a continuous rod withdrawal accident from low power. This can only occur during testing, when favorable weather conditions prevail. Hence, the early Consequence II accident would be bounding.

Another potentially serious event is a loss-of-coolant accident (LOCA). This accident can result in core melting or core vaporization, depending on the time during or after testing when cooling is lost. The difference between Source Term Levels 2 and 3 and the early or late accident Consequence II

for the LOCA depends on the window of weather predictability and the amount of fission and decay heat required to vaporize or melt the core. Current calculations indicate that conduction of decay heat to the reactor test article and assembly is sufficient to prevent melting if the LOCA occurs after about 3 hours following the end of operations. Since weather predictability is assumed to extend for about 10 hours, a LOCA occurring after about 3 hours would be limited to a source term of Level 3 or less. The consequences of this accident ("late LOCA") are significantly less than either the early or late consequence II accidents discussed in Section 2.4.2 (which used source term Level 2 rather than the more benign Level 3).

If the LOCA occurs in a time shorter than a few hours, ("early LOCA") core vaporization or melting is possible. Melting and movement of the fuel to a more compact geometry would result in a loss of reactivity, so that Level 3 would still bound the source term in the absence of vaporization due to reactivity insertion. For the early LOCA, weather patterns would be favorable. Hence, the early Consequence II accident that uses the Level 2 Source Term would be bounding, regardless of the degree of core melting or vaporization.

Long-Term Post Test Cooling

The test articles will remain within the test cell for an extended cooling period and to allow substantial decay of the radionuclides. Within this configuration, the source term would probably be substantially less than Level 4, since the moderate fission product inventory would be significantly mitigated by the presence of the ETS. Even in the extremely unlikely event of an inadvertent criticality with some inventory, the source term would be less than Level 2.

Maintenance and Inter-Test Period

As long as the test article remains within the confinement, source terms would be less than Level 2 credible mechanistic accident scenarios. The worst-case accident would be bounded by Consequence II "Late". However, the probability of such a consequence is extremely unlikely. In the analysis, no credible accident involving hydrogen detonations was capable of failing the reactor vessel (primary confinement) or any major component of the ETS. This was true either as a result of the structural strength of the component, or the impossibility of introducing oxygen into a hydrogen-pressurized system. Similarly, no mechanism was uncovered that would lead to recriticality as a result of a nearby hydrogen detonation.

Deinstallation, Storage, and Transportation

Since the radioactivity of the test article has substantially decayed, source terms should not exceed Level 4. Similarly, no physical mechanism was

identified by which criticality could occur as a result of an external explosion. The most serious event would involve a fragmentation and local dispersion of large core fragments; hence, the Source Term would not exceed Level 5. Transportation of radioactive material off site might involve accidents leading to dispersal of the material. However, these transportation accidents are separately considered.

Decommissioning

A detailed investigation of decontamination and decommissioning of the facility at the end of its useful life will be performed as part SAR process in the program. No environmental or safety impact is expected in this process that would exceed the accident consequences already examined in the earlier phases of the project.

2.4.2 Evaluation of Potential Accident Scenarios

Consequence I

A Consequence I accident is considered the maximum possible hypothetical accident. The accident assumes the total release of all radioactive material of a maximum inventory GTA core immediately following operation. The inventory is assumed to be released in a completely aerosolized fashion to maximize the radiological consequence. The release is assumed to bypass completely the ETS and any secondary confinement. No account for agglomeration, condensation, or scavenging processes is taken, which ensures that the maximum inventory is dispersed outside of the test site boundary. Each of these assumptions represents an overly-conservative bound which cannot be realized physically.

Consequence II

A Consequence II accident is considered the maximum credible postulated accident scenario. A Consequence II accident can result if a critical ETS component fails following the end of a maximum operational cycle, placing the maximum inventory into that component. The critical component is assumed to be the cryogenic adsorber beds (a series of multiple parallel stages) which are assumed to have the potential to fail any time during or following an operation. For conservatism, 100 percent of the core is assumed to be released into the ETS. For this case all of the noble gas inventory is released into the atmosphere, particulates and other non-gaseous materials are mainly trapped in the ETS particulate and charcoal filters, and thus not released. This accident is considered for PIPET only. It would require the simultaneous failure of three independent systems for a GTA reactor to experience this scenario (reactor core integrity ETS adsorber beds, and the ETS confinement system), which is considered unrealistic.

Two different failure times are considered. The first occurs immediately following the end of a PIPET Normal III operation. Model weather conditions are assumed, since this release would occur within the 10-hour forecast window. This accident is termed the Consequence II "Early" scenario.

The second time at which an adsorber bed can be assumed to have failed occurs after the 10-hour forecast window. For this reason nominal weather conditions can no longer be assumed. Instead, credible weather conditions which produce the maximal impact are assumed to prevail (F stability, 1.0 m/s wind speed, and a 300 m inversion layer base). Additionally, the wind is assumed to be blowing directly toward the nearest maximum population center (Las Vegas at NTS and Idaho Falls at INEL). This accident is termed the Consequence II "Late" scenario in the remainder of this section.

Consequence III

During initial installation of a GTA or PIPET core, some zero or low-power testing (Normal I operations) would be conducted. Although highly unlikely, an accidental reactor control rod withdrawal could occur before the reactor containment and confinement system are in place. In this event, the reactor would experience a brief, but intense, power excursion that could result in fuel vaporization and subsequent release directly into the atmosphere. The resulting inventory would contain fission products from approximately 10^{18} fission events (equivalent to 110 MW for 0.5 seconds of GTA operation) (Sherman, 1991), and would be released at ground level. Although the intent would be to perform the zero-power testing in at least model weather conditions, weather conditions producing the maximal impact are assumed for conservatism (F stability, 1.0 m/s wind speed, and a 300 meter inversion height). Additionally, the wind is assumed to be blowing directly toward the nearest maximum population center (Las Vegas at NTS and Idaho Falls at INEL).

Preliminary analysis performed using these accident scenarios has shown the Consequence II "Late" accident with a PIPET core to be the conservative bounding case scenario. Although greater impacts are calculated using a Consequence I accident, no credible design-based situation is conceivable which could result in its occurrence, thus it will not be considered in this analysis. The potential for occurrence of even a Consequence II type accident is remote, since it would depend upon the simultaneous failure of two independent reactor systems; failure of the complete ETS cryogenic adsorber system, and failure of the confinement or isolation system which would otherwise prevent uncontrolled release of radioactive material during an accident. The probability of such an occurrence, termed a "two-point" failure, is remote; while the failure of either system is low, the simultaneous failure of both is almost inconceivable.

2.4.3 Bounding Case Accident Impacts

Tables E-17 and E-18 list the MEI and population dose, respectively, for the Consequence II "Late" accident. The site boundaries for this accident are reported closer to the release point (23 kilometers at NTS, and 10 kilometers at INEL) than was used in the Normal-case operations analyses as a result of the wind direction changes.

Table E-17. PIPET, Consequence II "Late" Accident Plume Center-Line MEI

Site	Site Boundary		Peak		Annual Natural Radiation
	Dose (mrem)	Distance (km)	Dose (mrem)	Distance (km)	Dose (mrem)
NTS	23.5	23	23.5	23	422
INEL	24.0	3	30.0	10	441

The dose at the NTS boundary for this accident occurring at SMTS is approximately 23.5 mrem. The dose at the INEL site boundary for this accident occurring at CTF is approximately 24.0 mrem. MEI values are 23.5 mrem at NTS and 30.0 mrem at INEL. Although these values do not take into account the effects of evacuation they are well below the ANSI/ANS Report 15.7 guideline of 500 mrem (0.5 rem).

Population doses as a result of a Consequence II "Late" accident are evaluated in the southeast (SE) wind sector for NTS (i.e., Las Vegas), and the SE sector at CTF (i.e., Idaho Falls). The projected latent effects which may be caused by the Consequence II "Late" accident may be approximately 0.37 additional cancer fatalities and 0.12 additional genetic disorders at NTS, and approximately 1.4 additional cancer fatalities and 0.44 additional genetic disorders at INEL. These values represent the maximum accident-case impact for PBR propulsion technology assessments.

An initial analysis of a Consequence I accident, using a GTA core to yield the source term and occurring under model weather conditions, was undertaken. Impacts produced by such an accident, while recognized as not physically possible to produce, serve as a baseline against which the bounding case can be compared. At NTS, a GTA Consequence I accident could result in an MEI of 221 mrem at a distance of 180 kilometers, while at INEL such an accident would produce an MEI of 560 mrem at a distance of 120 kilometers.

Likewise at NTS a GTA Consequence I accident at NTS could produce as many as 0.17 additional cancer fatalities and 0.056 additional genetic

Table E-18. PIPET, Consequence II "Late" Accident 50-Year Population Dose

Site	Maximum Sector	Direct Exposed Population	Direct Pop. Dose (Person-mrem)	Ingestion Exposed Population	Ingestion Pop. Dose	Total Pop. Dose (Person-mrem)	Average Individual Dose (mrem)	Latent Cancer Fatalities	Genetic Disorders
NTS	SE	974,109	401,000	1,072,718	64,000	465,000	4.7×10^{-1}	3.7×10^{-1}	1.2×10^{-1}
INEL	SE	65,781	350,000	272,082	1,360,000	1,710,000	1.0×10^1	1.4×10^0	4.4×10^{-1}

disorders in the exposed population, and at INEL an additional 7.6 additional cancer fatalities and 2.5 additional genetic disorders.

3.0 RADIOLOGICAL IMPACTS OF TRANSPORTATION

The impacts of transporting feed, fresh product, irradiated product, transuranic (TRU) waste, and low-level waste (LLW) for the program were analyzed using the RADTRAN computer code developed by Sandia National Laboratories (SNL). This section describes this computational method and the analysis performed.

The purpose of this analysis is to provide a technical assessment of radiological and nonradiological risk associated with transportation of radioactive materials used for system development work at ground test facilities. This analysis does not assess "social amplification of risk," which may be affected by public perceptions (Kasperson et al., 1988). No generally accepted method has yet been developed for the formal analysis of these factors. However, awareness of these concerns is responsible, at least in part, for the recognition of "secondary factors" in the U.S. Department of Transportation (DOT) routing guidelines and for the strong tendency toward conservatism (i.e., toward overestimation of risk) in the risk analysis.

3.1 RADTRAN MODEL

The RADTRAN 4 risk analysis model was developed by SNL to calculate radiological risks associated with the transport of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge (Neuhauser and Kanipe, 1991, in preparation). The RADTRAN 4 computer code consists of two major modules for each transport mode: the incident-free transport module, in which doses resulting from normal transport are modeled; and the accident module, in which consequences and probabilities of accidents are evaluated and used to generate a risk estimate. RADTRAN 4 is the central code of the set of codes and databases developed by SNL to support transportation risk analysis. With these codes and databases, radiological and nonradiological transport risks can be estimated, and they are well suited to complex problems involving multiple package types, transport mode options, and potential destinations. RADTRAN 4 permits the user to describe route segments in detail. This capability is used in the present analysis to generate shipment-level risk values (Neuhauser and Kanipe, 1991, in preparation).

The single greatest "limitation" facing users of RADTRAN or any code of this type is a scarcity of statistical data for certain input parameters. This difficulty often can be overcome by using conservative estimates of these parameters (i.e., values that tend to maximize the risk). The resulting risks tend to be overestimates (Neuhauser and Reardon, 1986), but are

appropriate for use as bounding estimates in environmental documents. In this context, use of confidence limits as a measure of uncertainty would be inappropriate.

An extensive analysis of the sensitivity of RADTRAN risk calculations to variations in parameters was performed by Neuhauser and Reardon (1986) for a sample truck transport case. The parameters that had the greatest effect on the incident-free risk calculation for truck transport were found to be, in decreasing order of importance: exposure distance while stopped; package dose rate; packages per shipment; shipments per year; K_0 (a factor that accounts for the shape of the package); distance traveled; stop time; number of persons exposed while stopped; shipments per year; distance from source to crew; and number of crew members. All of these are either deterministic (i.e., have known, fixed values for the problem being analyzed) or can be appropriately bounded by a conservative assumption. The accident risk calculation was sensitive to values for release fraction and for probability of occurrence of accident-severity categories; it was relatively insensitive to changes in accident rate or fractions of travel in urban, suburban and rural population-density zones. Consequently, where data are not available, conservative assumptions regarding package release fractions and accident-severity-category probabilities are used.

3.1.1 Incident-Free Radiological Risk

Included in the incident-free module for highway and rail transport are models describing:

- Dose to persons within 800 meters (2,600 feet) of the transport link
- Dose to persons sharing the transport link
- Dose to persons at stops (e.g., refueling stops, rail classification yards).

The magnitude of this risk depends mainly on the package or shipment dose rate and the surrounding population densities. The package dose rate is defined as the dose rate in millirem per hour at 1 meter (3 feet) from the package surface. The shipment dose rate is defined as the corresponding dose rate at 1 meter from the conveyance. The latter is often used to model multiple-package shipments. Three population density zones (rural, suburban, and urban) are used for interstate highway routes. These correspond to mean population densities at 6, 719 and 3,861 persons per square kilometer (250 acres), respectively.

Radiological Accident Risk

Accident risk may be generically defined as the consequences of an accident multiplied by the probability of that accident. In practice, any number of different accident sequences exist, each of which has an associated probability. These various types of accident sequences may be grouped according to their severities; in RADTRAN, each of these groupings is considered an Accident Severity Category. Severity is a function of the magnitudes of the impact, puncture, and thermal forces to which a package may be subjected during an accident. Because all accidents may be described in terms of these basic physical forces, severity is scenario-independent. That is, any sequence of events that results in an accident in which a package is subjected to forces within a certain range is assigned to the Accident Severity Category associated with that range of values. Each value in the severity category matrix represents a conditional probability. This is, each value is the probability, given that an accident occurs, that it will be of that particular severity. To determine the expected frequency of each severity category, each value must be multiplied by the baseline accident rate for the mode and population zone. Each population density zone has a distinct baseline accident rate and distribution of accident severities because of differences in average velocity, traffic density, and other factors in rural, suburban, and urban areas.

Radiological consequences were calculated by assigning release fractions to each category for each chemically and physically distinct type of radioisotope. The release fraction is defined as that fraction of the radioisotope group in the package that could be released in a given severity of accident. Release fractions vary by package type. Most solid materials are relatively nondispersible and would be difficult to release in particulate form. Therefore, RADTRAN allows the user to assign values for aerosolized and respirable aerosol fractions of the released radioactive material for each Accident Severity Category. Distinct aerosol and respirable aerosol fractions are assigned by material dispersibility category; these categories describe the physical form of the material (e.g., gas, liquid, solid in power form, monolithic or nondispersible solid).

RADTRAN contains a meteorological model that allows the user to define the behavior of a plume of particulates, if one is produced by the type of accident considered. Material released in aerosol form is assumed to travel away from the immediate vicinity of an accident in a particulate plume.

To calculate health effects, five exposure pathways are considered:

- Inhalation of respirable aerosols in the passing plume
- Cloudshine, defined as exposure to penetrating radiation (e.g., gamma radiation) from the passing plume

- Groundshine, defined as exposure to penetrating radiation from radioactive material that is deposited on the ground from the plume
- Resuspension, defined as inhalation dose from respirable aerosols that are deposited on the ground by the passing plume and subsequently resuspended
- Ingestion, defined as exposure from ingestion of agriculture products from areas contaminated by particulates from the plume (rural zones only).

Cloudshine and inhalation of respirable aerosols occur only while persons are exposed to the plume. Since persons outdoors would be most directly affected, RADTRAN allows the user to account for pedestrian densities in urban areas. Groundshine, resuspension, and ingestion doses would be incurred at later times, and their magnitudes would depend in part on how rapidly a contaminated area is evacuated and whether the area is cleaned up or restricted from use. RADTRAN allows the user to estimate evacuation times, and it includes contamination thresholds for determining whether interdiction or cleanup will occur. The cleanup level is in accordance with proposed U.S. Environmental Protection Agency (EPA) guidelines.

3.1.2 Total Radiological Risk of Transport

A unit-shipment approach was used to calculate transportation risk. The risk per shipment is calculated and multiplied by the number of shipments of each material type. These products may then be summed to give total risk values.

3.1.3 Nonradiological Risk of Transport

The RADTRAN postprocessor performs calculations for nonradiological unit-risk factors (e.g., risk of fatality from mechanical injury) to determine total nonradiological risks. Note that for these risks the two-way travel distance is used because, while radiological risks may be incurred only for a shipment containing radioactive material, nonradiological risks are equally likely when the transport vehicle is traveling empty.

3.1.4 Representative Routes

For truck transport, to estimate the fraction of travel in each population density zone, representative interstate highway routes are generated for each origin-destination combination, and population densities along these routes are determined from 1980 census data. These data and one-way mileage estimates are generated by a highway routing code.

3.2 ANALYSIS

3.2.1 Input Data and Modeling of Packages/Shipments

RADTRAN requires substantial amounts of input data to adequately model the packaging, the packaging contents, the vehicle and transport link, and potential radiological consequences. In addition, a conditional probability must be assigned to each Accident Severity Category for each population-density zone, and accident rates for each vehicle type and transport mode must be determined. Many of these values do not change for a specific application. For example, interstate highway lane dimensions do not change regardless of what vehicle type or payload is being analyzed. Since predetermined default values are used for these parameters, the user needs to consider only the values of those parameters that may change as a result of program-specific conditions. In this section, program-specific conditions and related input values are discussed and documented.

Shipments of high-enriched uranium feed material would be received from Oak Ridge, Tennessee. All uranium feed material shipments, for analysis purposes, were considered to be in oxide form. The uranium feed material would be converted to "fresh product" at Lynchburg, Virginia. From Lynchburg, the fresh product would be transported to Albuquerque, New Mexico, where small quantities could be irradiated in existing facilities at SNL or transported to one of the potential sites of the new validation test facility. At either the SNL or new validation test facility locations, the fresh product material would be irradiated in a reactor environment for cumulative time periods ranging from a few seconds to a few thousand seconds. Following this irradiation and subsequent on-site examination, the irradiated product material would be subject to one of the following options:

- Option 1: Shipment to an off-site hot cell facility for further examination.
- Option 2: Shipment to a processing facility for recovery and recycle of high-enriched uranium (also for unused fresh product).
- Option 3: Treatment as waste for either on-site or off-site disposal depending on the given site's waste acceptance criteria.

If the irradiated product material is shipped to an off-site hot cell for further examination, the final disposition would be through either Option 2 or 3 above.

LLW would be generated during testing operations. These LLW waste forms could include filter media, particulates, activated hardware, and contaminated structural materials. The LLW would be disposed of on site. Waste meeting the TRU waste acceptance criteria could not be demonstrated to be produced during operations, but for conservatism

testing operations were modeled as generating sufficient TRU waste to account for a single shipment to the Waste Isolation Pilot Plant (WIPP).

A set of conservative baseline conditions was defined for analysis to provide a point of comparison for relative risk assessments. Briefly, each material would be shipped by truck; shipments of feed, fresh product, and irradiated product materials going for further examination or recovery and recycle processing would be carried in safe secure transports (SSTs) or by appropriately safeguarded commercial truck. All of the fresh and irradiated product was assumed to be shipped by commercial truck for this analysis. The TRU waste would be grouted and shipped off site by commercial carriers in Type A packages (55-gallon drums) in TRUPACT-II Type B overpacks; the LLW would be packaged according to all applicable regulations and hauled to an on-site LLW disposal facility. The structural materials that might be LLW were all modeled as being broken down into units small enough to fit into 55-gallon drums with a 50-percent void volume factor accounted for. In actuality, it is probable that at least some of these structural materials would be shipped as low-specific-activity material in bulk form, which would greatly reduce the number of such shipments. Therefore, the risk values given for LLW transportation in this analysis are conservative. A summary of the packaging assumptions used in the analysis is given in Table E-19.

In prior analyses of similar materials (DOE/EIS-0136), two shipment sizes (full and half-full loads) were analyzed. This was considered because it was possible that a reduced payload might decrease the consequences of a severe accident and thus reduce the overall risk. The results of this earlier analysis indicate that, although there was some reduction in high-severity accident consequences, this was more than offset by the increase in risk resulting from the fact that twice as many shipments must be made to transport the same amount of material. Therefore, only full loads are considered in this analysis.

All LLW generated during operations of the proposed new test facility is modeled as being disposed of on site. This waste would consist primarily of fission-product-contaminated material and activated structural materials. The former was modeled as containing the maximum amount of the given material that can be carried in a Type A package. For all materials modeled (filter media, etc.) this amount still contains less than 100 nanocuries per gram of alpha-contaminated material, which is the maximum concentration of alpha-emitting isotopes permitted in LLW, thus the analysis is conservative.

The total output of LLW from operations is expected to be about 1.7×10^6 metric ton with a volume of 46,000 cubic meters (1.6 million cubic feet) (includes 50 percent packing volume allowance), which is equivalent to about 219,250 55-gallon drums. The radionuclide inventory of a package

Table E-19. Packaging Assumptions Used in Analyses

Material	Package Type	Estimated Percent of Material	Radioactive Material Form and Content	Radiation Dose Transport Index (TI) per Package	Estimated Packages per Shipment	Transport Carrier
Feed	6M	100	uranium oxide (UO ₂) powder	10.0*	3 or 13	SST
Fresh Product	Type A-fissile	100	encapsulated	10.0	2 or 37	Commercial Truck
Irradiated Product	Type A-fissile	5	encapsulated	10.0	1	Commercial Truck
	Type B-fissile	95	encapsulated	10.0	2 or 37	Commercial Truck
Material for Recycle	6M	100	encapsulated	10.0	3 or 25	SST
LLW	Low-Specific Activity (LSA)	0**	bulk; special form	10.0		On-site or Commercial Truck
	Type A	95	various	10.0	72 drums	Commercial Truck
	Type B	5	various	10.0	1	Commercial Truck
TRU	Type A Drum in Type B TRUPACT-II	100		10.0	42	Commercial Truck
Mixed LLW	Type A Drums	100	various	10.0	50	On-site Truck

* Maximum regulatory value used as default.

** No LSA used in analysis, but some Type A LLW could be shipped as LSA.

varies from 2 to almost 40 curies; the latter applies only to special form material. Although the transport distance could vary at the two alternative sites for the new test facility, a maximum distance of 50 kilometers (approximately 30 miles) was used for both sites. The average velocity on site was assumed to be 50 kilometers per hour (about 30 miles per hour).

Stop times associated with transport by SST differ from those for commercial truck transport. Stop time was set at 0.0021 hour per kilometer in accordance with safe operating procedures for the SST (Mulryan, 1987). The value for commercial truck transport is 0.011 hour per kilometer which was used for all other off-site shipments. The operating procedures for the SST are classified.

Representative interstate highway routes from each potential origin to each potential destination were generated by the INTERSTAT routing highway code, which also gives fractions by travel in rural, suburban, and urban population density zones (Cashwell, 1987) and total one-way distance. These are listed in Tables E-20 and E-21.

The INTERSTAT routing network includes the interstate highway system, state-designated alternate routes, and access routes into various DOE facilities. Because of their high and uniform levels of engineering and safety, the interstate highways have been identified by the DOT as the preferred routes for transport of highway-route-controlled quantities of radioactive materials (formerly called large-quantity shipments); where available, urban beltways and bypasses must be used. States and tribes may designate alternative routes when the designation is accompanied by a safety analysis demonstrating equal or greater levels of safety.

The accident rates used in the analysis are from DOT data for the entire commercial shipping industry (i.e., accidents on interstate highways involving at least one commercial tractor-trailer regardless of payload), and are based on millions of total vehicle-kilometers of travel. Available unclassified accident/incident data for radioactive materials shipments indicate, for example, that for the 11-year period from 1971 to 1982, fewer than thirty Type B packages were involved in truck or rail accidents (Wolff, 1984). There was no release of radioactive material in any of these accidents. An accident rate derived from this information should not be used; the statistical significance would be questionable because the total truck-kilometers involved are relatively small and because few accidents occurred. Therefore, the accident rates in this analysis are conservatively set equal to the national average accident rates for commercial tractor-trailers. The national average rates are derived from DOT data and are appropriate for relatively long-distance routes that traverse several states. SNL has conducted a number of tests to demonstrate the validity of this conclusion. The average for the entire United States is 3.1×10^{-7} accidents per kilometer (4.0×10^{-7} accidents per mile). The limited variability in

Table E-20. Transportation Quantities and Distances for Proposed Shipments that are Independent of Site Alternatives

Origin	Destination	Material	Number of Shipments	Kilometers per Shipment	Estimated Percent of Travel		
					Rural	Suburban	Urban
Oak Ridge, TN	Lynchburg, VA	Feed	50	526	67.7	31.2	1.1
Lynchburg, VA	Albuquerque, NM	Fresh Product	1	2,731	76	23	1.1
Albuquerque, NM	Lynchburg, VA	Irradiated Product	1	2,731	76	23	1.1
Albuquerque, NM	Oak Ridge, TN	Material for Recycle	1	2,205	78	21	1.0
Lynchburg, VA	Oak Ridge, TN	Material for Recycle	1	526	68	31	1.0
Test Location	Disposal Location	Low Level	3,523*	50	100	0	0

* Includes 11 shipments of mixed waste to on-site mixed-waste-processing facility.

Table E-21. Transportation Quantities and Distances for Site Alternatives

Alternative	Site	Origin	Destination	Material	Estimated Number of Shipments	Kilometers per Shipment	Percent of Travel		
							Rural	Suburban	Urban
1	NTS	Lynchburg, VA	Albuquerque, NM	Fresh Product	83	2,731	76	23	1
		Albuquerque, NM	Mercury, NV	Fresh Product	83	1,043	87	12	1
		Mercury, NV	Albuquerque, NM	Irradiated Product	83	1,043	87	12	1
		Albuquerque, NM	Lynchburg, VA	Irradiated Product	83	2,731	76	23	1
		Mercury, NV	Carlsbad, NM	TRU Waste	1	1,492	87	12	1
2	INEL	Lynchburg, VA	Albuquerque, NM	Fresh Product	83	2,731	76	23	1
		Albuquerque, NM	Idaho Falls, ID	Fresh Product	83	1,801	87	12	1
		Idaho Falls, ID	Albuquerque, NM	Irradiated Product	83	1,801	87	12	1
		Albuquerque, NM	Lynchburg, VA	Irradiated Product	83	2,731	76	23	1
		Idaho Falls, ID	Carlsbad, NM	TRU Waste	1	2,250	87	12	1

* On-site transportation of LLW is assumed to be 50 kilometers (30 miles) for all sites. Transport quantities and distances are shown in Table E-20.

accident rates supports the use of national average data for the program shipments. These accident rates were also used for on-site shipments. This is a conservative approach because lower speeds and institutional controls are expected to lower actual on-site accident rates.

These rates are for all reported combination truck accidents on interstate highways. The possibility of the very severe accidents which would be required to result in a release of radioactive material is much lower. The overall frequency of under-reporting of accidents is about 40 percent for property-damage-only accidents; the reporting of serious and fatal accidents is virtually 100 percent (Smith and Wilmot, 1982). Thus, the base accident rate is not adjusted for under-reporting, since doing so would serve only to raise the relative frequency of occurrence of low-severity accidents and lower the relative frequency of occurrence of high-severity accidents, which would remove a certain level of conservatism in the accident-risk calculation. The eight-category Accident Severity Category matrix for commercial truck transport from NUREG-0170 (Nuclear Regulatory Commission [NRC], 1977) is used.

Restricting truck transport to good weather conditions reduces the overall truck accident rate by about 10 percent (NUREG-0170-Section 6.3.3). Since accidents associated with travel in poor weather conditions are included in the DOT accident-rate data that were used in the risk analysis, the risk estimate is slightly conservative with respect to this parameter. In the unlikely event of an unforeseen road closure, radiological impacts would be associated mainly with an increase in stop time and perhaps an increase/decrease in distance traveled (e.g., if a vehicle were able to use an alternate route). Since only one or a few shipments would be affected on an annual basis, the overall annual incident-free risk estimate would not change significantly.

The SST would be used to transport program-related shipments of feed and recycle material. An SST may be, but was not assumed to be, used for fresh and irradiated product shipments. The SST acts as a significant secondary barrier; it provides additional shielding that reduces the external dose rate of the shipments, and it provides additional levels of accident resistance. For shipments of TRU waste to the WIPP, the TRUPACT-II would be used. Release fractions for a typical Type B package were used (NRC, 1977) to represent the TRUPACT-II, and no credit was taken for any protection that might be afforded by the inner Type A packages (drum). The LLW low-specific activity and Type A packages were modeled as typical Type A packages.

The 6M is one of the few packagings for which a large amount of data exists on response to the higher severity category accidents, and the release fraction values used here and in earlier studies are based on these data (Bonzon, 1977; Fischer et al., 1987). It is expected that the 6M will be

replaced by a newer packaging of the same type with an improved closure mechanism. However, other basic features of the packaging would remain the same, and the new Type B inner packaging is modelled in this analysis as having the same properties as a 6M. The accident resistance provided by the SST is significant. The high integrity of the trailer acts as an impact-force-reducing barrier and provides thermal protection. The release fractions assigned to the Type B packaging in Accident Severity Categories VI, VII, and VIII for the 6M inner packaging must be modified to reflect the protection afforded a shipment by the SST. Lesser accident categories (I through V) result in no release of material to the environment (NRC, 1977).

The SST also provides enhanced thermal protection, being capable of withstanding temperatures in excess of the regulatory test-fire temperature [1,475° F (800° C)] for periods exceeding the test duration of 30 minutes without significant elevation of internal temperature (SNL, 1976). The SST provides additional thermal protection such that the Type B packagings, which are themselves highly fire-resistant, would not directly experience thermal loads characteristic of a Category VI fire. Note that both fire and impact forces of the magnitudes defined above are required for an accident to be classified as Accident Severity Category VI; this is also true of the definitions of Categories VII and VIII. The SST so effectively prevents either of these conditions from affecting the payload that a Category VI accident would not result in any release of contents. Therefore, the release fraction for this severity category is equal to zero for shipments of the Type B/SST configuration. For shipments of the Type A/SST configuration, the release fraction for Category VI was set equal to 0.01. Since Type A packages subject to severe impact loadings encountered in Categories VII and VIII must be assumed to fail completely, the SST was conservatively modeled as providing no additional protection in these two highest categories.

The forces a shipment may experience in Category VII accidents [140,000-230,000 kilograms (300,000-500,000 pounds)], if applied uniformly to the SST, would not result in crush forces in the interior of the trailer that exceeded the Type B failure threshold. However, concentrated application of such forces could cause local deformation of the SST. Crush forces on packagings in the immediate vicinity of the impact point could exceed the Type B threshold. Forces of that magnitude are seldom encountered in actual accidents. A grade-crossing accident involving a train moving at high velocity could conceivably provide the requisite force at a 90-degree impact angle, and the force would be concentrated in a relatively small area rather than being uniformly distributed. Therefore, for the purposes of this study, all accidents of this severity are modeled conservatively as being of the local-deformation type. For a close-packed array of Type B packages, four packages in the immediate vicinity of the local deformation would be affected. The four packages damaged by crush forces generated as a result of impact could be subjected to a Category VII fire [800° C (1,475°F) for up to 2 hours] and could release some fraction of their contents. The

release fraction for each shipment was then conservatively set equal to the product of the fraction of affected Type Bs and the release fraction for a Type B in a Category VII accident (as defined in NUREG-0170 using Model II). For SSTs carrying Type A packages, all Type A packages were modeled as failing completely in a hypothetical Category VII.

Accident Severity Category VIII, as defined in NUREG-0170 (NRC, 1977) for highway transport, includes accidents involving both forces greater than 230,000 kilograms (500,000 lbs) and fires over 2 hours in duration at 800° C (1,475°F) (or equivalent thermal load). No highway accident this severe has ever been recorded, so for the purposes of this study the local-deformation scenario used in Category VII was extended. Six Type Bs would be damaged as a result and subjected to fire. The shipment release fraction is again conservatively set equal to the product of the fraction of affected Type Bs and the release fraction for a Type B package in a Category VIII accident (as defined in NUREG-0170). For SSTs carrying Type A packages, all Type A packages were modeled as failing completely in a hypothetical Category VIII accident.

Aerosol and respirable aerosol fraction values for dispersibility category 5 (loose, small powder) are used for feed material (NRC, 1977). They determine the amounts of material that may be dispersed and eventually inhaled in each severity category in which a release may occur. The fraction of airborne material that is less than 10 microns in size (mean aerodynamic diameter) and that could therefore enter the human respiratory system (International Commission on Radiological Protection [ICRP], 1979) was set at 50 percent for feed. Ninety percent (mass percentage) of all inhaled airborne particles between 10 and 20 microns (mean aerodynamic diameter) and 100 percent of all particles over 20 microns (mean aerodynamic diameter) are deposited in the nasopharyngeal region. Respirable aerosols may be generated by impact forces and, more importantly, by fire. The uranium oxide, although it will not burn, is more dispersible when in powder form, and this was accounted for in the analysis by the dispersability category assignment. The respirable aerosols potentially generated in severe accidents are, therefore, estimated in a conservative, material-specific manner. The deposition velocity of all released particulates was set at the default value of 0.03 feet per second (0.01 meters per second), which is representative of aerosols. The fraction of all radionuclides that would be deposited on agricultural land and then transferred to food products was set equal to 2.8×10^{-6} (Ostmeyer, 1986).

The fresh product is a very high integrity material. Even under very severe mechanical and thermal loadings to the fresh product package, more than 99 percent of the material would remain intact. Therefore, aerosol and respirable aerosol fraction values for a similar high-integrity material (Fort St. Vrain power reactor fuel) are used for fresh product. The irradiated product and material for recycle also are assigned aerosol and respirable

aerosol fraction values like those used for Fort St. Vrain power reactor spent fuel.

Aerosol and respirable aerosol fractions similar to those used for ordinary commercial shipments of Type A packages are used for low-level waste, and TRU waste is modeled as described in the WIPP SEIS. These values are typically used in RADTRAN evaluations of the shipment of these materials for environmental evaluations.

For this analysis, RADTRAN results are given in terms of population dose (i.e., person-rem) per shipment. To obtain risk in terms of health effects, these values are multiplied by the total number of shipments of the appropriate material type and by health effect estimators discussed in a BEIR model. The effective whole-body doses calculated by RADTRAN were reduced by a factor of 2 to yield gonadal dose for genetic risks as suggested by the ICRP (ICRP, 1977).

3.3 RESULTS

Radiological unit-risk factors from the RADTRAN System are expressed in units of expected dose (person-rem) and health effects (cancer deaths and genetic effects) per shipment for each type of shipment. Risk factors are calculated separately for the public under incident-free and accident conditions. The representation of each of the three population zones (rural, suburban, and urban) is indicated in the route data given in Tables E-20 and E-21.

Nonradiological risks are deaths arising from traffic accidents (mechanical injuries) and deaths from respiratory ailments resulting from vehicular air pollution (Rao, Wilmot, and Luna, 1981). Nonradiological unit-risk factors based on national statistics were obtained from DOT data.

In this analysis, the entire package dose rate was modeled as gamma radiation, which tends to overestimate total integrated dose because neutrons are rapidly attenuated in air whereas gamma radiation is not. Since the exact packaging configuration to be used has not been identified, the Transport Index (TI) was assumed to be the maximum value allowable for these shipments. This results in a very conservative estimate of radiation doses for incident-free shipments. Typically, the surface dose rates on SNTP packages shipped over public highways will be very low (since many are unirradiated materials) and realistically could be orders of magnitude lower than were assumed for these transportation impact calculations. Consequently, the incident-free radiological impacts should be much lower than those calculated.

The per shipment risk values are multiplied by the expected number of shipments of each material type to give total risks for each. The per

shipment and total radiological risks for transporting feed, fresh product, irradiated product, material for recycle, and TRU waste are given in Tables E-22 and E-23, respectively. The number of genetic effects is 40 percent of the number of cancer deaths shown in these tables. The risk to the public from transportation of low-level and hazardous wastes that are to be treated and disposed of on-site is negligible. Total radiological risks for the NTS and INEL alternatives are given in Tables E-24 and E-25. The total nonradiological risk of an accident-related fatality is 0.206 for NTS and 0.232 for INEL. Total nonradiological transportation risks are given in Table E-26.

Table E-27 is a summary of total radiological and non-radiological risks for all materials that includes both the risks for incident-free conditions and the risks for accident conditions. The radiological risks of transportation result mainly from the transport of fresh product. Most of the radiological risk is attributable to incident-free transport. That is, potential accidents contribute little to the total radiological risks. Nonradiological risks are about 2 times higher than radiological risks and would result from mechanical injuries from traffic accidents. Using a more realistic assumption on Transport index (TI) in the RADTRAN Calculations would result in the non-radiological risk remaining the same and the radiological risk being much smaller. The predicted number of traffic accident fatalities of 0.206 to 0.232 is very small in comparison with the thousands of traffic deaths on American highways each year.

4.0 ON-SITE CONTAMINATION

4.1 DISTRIBUTION OF CORE CONTENTS FOLLOWING HYDROGEN EXPLOSION

Two mechanisms are available for dispersing the core particles: ballistic flight from shock imparted momentum and lofting by fireball winds. The latter was determined to be the most important because particle deceleration in the former case is governed by the particle relaxation time which is short compared with the time for fireball rise.

The approach to determining particle distribution involved performing a hydrodynamic cloud rise calculation to model the rise of a hot gas bubble that is grossly consistent with the fireball produced from a hydrogen/air detonation. The calculation was initialized in a manner that was consistent with the following assumptions:

1. The hydrogen/air detonation involved 30,000 gallons of liquid hydrogen that somehow became stoichiometrically mixed with air and detonated. The detonation involved an energy release of 1.61×10^{12} Joules; some time after detonation, the fireball was a surface hemisphere with a

Table E-22. Radiological Transportation Risk (person-rem per shipment)
Page 1 of 2

Shipment Type	Route	Person-rem/shipment	
		Incident-Free*	Accident
Fresh Prod 2-element	Lynchburg-NTS	7.91×10^{-1}	1.68×10^{-12}
	Lynchburg-INEL	9.44×10^{-1}	1.90×10^{-12}
Fresh Prod 37-element	Lynchburg-NTS	7.91×10^{-1}	3.12×10^{-12}
	Lynchburg-INEL	9.44×10^{-1}	3.53×10^{-12}
Feed	ORNL-Lynchburg	1.16×10^{-1}	2.94×10^{-8}
Irradiated Product 2-element	NTS-Lynchburg	4.01×10^{-1}	5.21×10^{-6}
	INEL-Lynchburg	4.78×10^{-1}	5.88×10^{-6}
Irradiated Product 37-element	NTS-Lynchburg	4.01×10^{-1}	9.61×10^{-6}
	INEL-Lynchburg	4.78×10^{-1}	1.09×10^{-4}
Experimental Product 4 kg	ALBQ-Lynchburg	2.09×10^{-1}	4.78×10^{-12}
Material for Recycle	ALBQ-ORNL	4.65×10^{-1}	1.95×10^{-6}
	Lynchburg-ORNL	1.16×10^{-1}	5.69×10^{-6}
	ALBQ-Lynchburg	5.81×10^{-1}	2.04×10^{-6}

* Based on TI = 10 for all shipments.

Table E-22. Radiological Transportation Risk (person-rem per shipment)
Page 2 of 2

Shipment Type	Route	Person-rem/shipment	
		Incident-Free*	Accident
Low-Level Wastes:			
Concrete & Steel	NTS-NTS	2.00×10^{-3}	2.16×10^{-12}
	INEL-INEL	2.00×10^{-3}	2.16×10^{-12}
Aluminum	NTS-NTS	2.00×10^{-3}	7.87×10^{-14}
	INEL-INEL	2.00×10^{-3}	7.87×10^{-14}
ETS-filters	NTS-NTS	2.00×10^{-3}	3.53×10^{-12}
	INEL-INEL	2.00×10^{-3}	3.53×10^{-12}
ETS-gravel	NTS-NTS	2.00×10^{-3}	4.71×10^{-13}
	INEL-INEL	2.00×10^{-3}	4.71×10^{-13}
ETS-silica	NTS-NTS	2.00×10^{-3}	4.71×10^{-13}
	INEL-INEL	2.00×10^{-3}	4.71×10^{-13}
ETS-struct	NTS-NTS	2.00×10^{-3}	2.72×10^{-11}
	INEL-INEL	2.00×10^{-3}	2.72×10^{-11}
Copper	NTS-NTS	2.00×10^{-3}	1.33×10^{-8}
	INEL-INEL	2.00×10^{-3}	1.33×10^{-8}
Beryllium	NTS-NTS	2.00×10^{-3}	2.75×10^{-16}
	INEL-INEL	2.00×10^{-3}	2.75×10^{-16}
Graphite	NTS-NTS	2.00×10^{-3}	5.95×10^{-19}
	INEL-INEL	2.00×10^{-3}	5.95×10^{-19}
High-Activity ETS Waste:			
ZiC-Graph	NTS-NTS	2.00×10^{-3}	1.60×10^{-13}
	INEL-INEL	2.00×10^{-3}	1.60×10^{-13}
Aluminum	NTS-NTS	2.00×10^{-3}	5.05×10^{-10}
	INEL-INEL	2.00×10^{-3}	5.05×10^{-10}
Structural	NTS-NTS	2.00×10^{-3}	5.06×10^{-10}
	INEL-INEL	2.00×10^{-3}	5.06×10^{-10}
TRU Waste:			
TRU	NTS-WIPP	8.49×10^{-3}	1.74
	INEL-WIPP	1.28×10^{-2}	2.62
Mixed Waste:			
Mixed	NTS-NTS	9.82×10^{-3}	1.24×10^{-6}
	INEL-INEL	9.82×10^{-3}	1.24×10^{-6}

* Based on TI = 10 for all shipments.

**Table E-23. Total Radiological Transportation Risks
(person-rem)
Page 1 of 2**

Shipment Type	Route	Shipment Number	Incident-Free*	Accident
Fresh Prod (2-element)	Lynchburg-NTS	80	6.31×10^1	1.35×10^{-10}
	Lynchburg-INEL	80	7.55×10^1	1.52×10^{-10}
Fresh Prod (37-element)	Lynchburg-NTS	3	2.37×10^0	9.36×10^{-11}
	Lynchburg-INEL	3	2.83×10^0	1.06×10^{-10}
Feed	ORNL-Lynchburg	50	5.80×10^0	1.47×10^{-9}
Irradiated Product (2-element)	NTS-Lynchburg	80	3.21×10^1	4.17×10^{-4}
	INEL-Lynchburg	80	3.82×10^1	4.70×10^{-4}
Irradiated Product (37-element)	NTS-Lynchburg	3	1.20×10^0	2.89×10^{-4}
	INEL-Lynchburg	3	1.43×10^0	3.27×10^{-4}
Experimental Product 4 kg	ALBQ-Lynchburg	1	2.09×10^{-1}	4.78×10^{-12}
Material for Recycle	ALBQ-ORNL	1	4.65×10^{-1}	1.95×10^{-5}
	Lynchburg-ORNL	1	1.16×10^{-1}	5.69×10^{-5}
	ALBQ-Lynchburg	1	5.81×10^{-1}	2.04×10^{-5}
Low-Level Wastes:				
Concrete & Steel	NTS-NTS	612	1.22×10^0	1.32×10^{-9}
	INEL-INEL	612	1.22×10^0	1.32×10^{-9}
Aluminum	NTS-NTS	148	2.96×10^{-1}	1.17×10^{-11}
	INEL-INEL	148	2.96×10^{-1}	1.17×10^{-11}
ETS-filters	NTS-NTS	143	2.86×10^{-1}	5.05×10^{-10}
	INEL-INEL	143	2.86×10^{-1}	5.05×10^{-10}
ETS-gravel	NTS-NTS	143	2.86×10^{-1}	6.74×10^{-11}
	INEL-INEL	143	2.86×10^{-1}	6.74×10^{-11}

* Based on TI = 10 for all shipments.

Table E-23. Total Radiological Transportation Risks
(person-rem)
Page 2 of 2

Shipment Type	Route	Shipment Number	Incident-Free*	Accident
ETS-silica	NTS-NTS	143	2.86×10^{-1}	6.74×10^{-11}
	INEL-INEL	143	2.86×10^{-1}	6.74×10^{-11}
ETS-struct	NTS-NTS	2319	4.64×10^0	6.31×10^{-8}
	INEL-INEL	2319	4.64×10^0	6.31×10^{-8}
Copper	NTS-NTS	1	2.00×10^{-3}	1.33×10^{-8}
	INEL-INEL	1	2.00×10^{-3}	1.33×10^{-8}
Graphite	NTS-NTS	1	2.00×10^{-3}	5.95×10^{-19}
	INEL-INEL	1	2.00×10^{-3}	5.95×10^{-19}
High-Activity ETS Waste:				
ZiC-Graph	NTS-NTS	1	1.98×10^{-3}	1.60×10^{-13}
	INEL-INEL	1	1.98×10^{-3}	1.60×10^{-13}
Aluminum	NTS-NTS	1	1.98×10^{-3}	5.05×10^{-10}
	INEL-INEL	1	1.98×10^{-3}	5.05×10^{-10}
Structural	NTS-NTS	1	1.98×10^{-3}	5.06×10^{-10}
	INEL-INEL	1	1.98×10^{-3}	5.06×10^{-10}
Beryllium	NTS-NTS	1	2.00×10^{-3}	2.75×10^{-15}
	INEL-INEL	1	2.00×10^{-3}	2.75×10^{-15}
TRU Waste:				
TRU	NTS-WIPP	1	8.49×10^{-3}	1.74×10^{-10}
	INEL-WIPP	1	1.28×10^{-2}	2.62×10^{-10}
Mixed Waste:				
Mixed	NTS-NTS	11	1.08×10^{-1}	1.36×10^{-4}
	INEL-INEL	11	1.08×10^{-1}	1.36×10^{-4}

* Based on TI = 10 for all shipments.

Table E-24. Radiological Transportation Risks for NTS Alternative
Page 1 of 2

Alternative	Dose in Person-rem		LCFs*	
	Incident-Free**	Accident	Incident-Free	Accident
Fresh Prod (2)	6.31×10^1	1.35×10^{-10}	4.98×10^{-2}	1.07×10^{-13}
Fresh Prod (37)	2.37×10^0	9.36×10^{-11}	1.88×10^{-3}	7.39×10^{-14}
Fresh Prod Total	6.55×10^1	2.29×10^{-10}	5.17×10^{-2}	1.80×10^{-13}
Feed:ORNL-Lynch	5.80×10^0	1.47×10^{-8}	4.58×10^{-3}	1.16×10^{-8}
Irrad Prod (2)	3.21×10^1	4.17×10^{-4}	2.54×10^{-2}	3.30×10^{-7}
Irrad Prod (37)	1.20×10^0	2.89×10^{-4}	9.48×10^{-4}	2.29×10^{-7}
Irrad Prod Total	3.33×10^1	7.06×10^{-4}	2.54×10^{-2}	5.59×10^{-7}
Experimental Product	2.09×10^{-1}	4.78×10^{-12}	1.66×10^{-4}	3.78×10^{-15}
Recycle Route 1	4.65×10^{-1}	1.95×10^{-5}	3.68×10^{-4}	1.54×10^{-8}
Recycle Route 2	1.16×10^{-1}	5.69×10^{-5}	9.16×10^{-5}	4.50×10^{-8}
Recycle Route 3	5.81×10^{-1}	2.04×10^{-5}	4.60×10^{-4}	1.61×10^{-8}
Recycle Total	1.16×10^0	9.68×10^{-5}	9.20×10^{-4}	7.65×10^{-8}
LLW:				
Concrete & Steel	1.22×10^0	1.32×10^{-9}	9.64×10^{-4}	1.04×10^{-12}
Aluminum	2.96×10^{-1}	1.17×10^{-11}	2.34×10^{-4}	9.24×10^{-15}
ETS-filters	2.86×10^{-1}	5.05×10^{-10}	2.26×10^{-4}	4.00×10^{-14}
ETS-gravel	2.86×10^{-1}	6.74×10^{-11}	2.26×10^{-4}	5.32×10^{-14}
ETS-silica	2.86×10^{-1}	6.74×10^{-11}	2.26×10^{-4}	5.32×10^{-14}
ETS-struct-1	4.64×10^0	6.31×10^{-8}	3.67×10^{-3}	4.99×10^{-11}
Copper	2.00×10^{-3}	1.33×10^{-8}	1.58×10^{-6}	1.05×10^{-11}
Graphite	2.00×10^{-3}	5.95×10^{-19}	1.58×10^{-6}	4.71×10^{-22}
ETS-struct-2***	1.98×10^{-3}	5.06×10^{-10}	1.56×10^{-6}	4.00×10^{-13}
Beryllium***	2.00×10^{-3}	2.75×10^{-15}	1.58×10^{-6}	2.18×10^{-18}
LLW Total	7.02×10^0	7.78×10^{-8}	5.55×10^{-3}	6.19×10^{-11}

* Conversion factor = 7.9×10^{-4} LCF/person-rem (BEIR VI).

** Based on package dose rate (TI) = 10 as default.

*** Originally treated as high-activity waste but evaluation indicates that material is LLW.

Table E-24. Radiological Transportation Risks for NTS Alternative
Page 2 of 2

Alternative	Dose in Person-rem		LCFs*	
	Incident-Free**	Accident	Incident-Free	Accident
High Activity ETS Waste:				
ZiC-Graphite	1.98×10^{-3}	1.60×10^{-13}	1.56×10^{-6}	1.26×10^{-16}
Aluminum	1.98×10^{-3}	5.05×10^{-10}	1.56×10^{-6}	4.00×10^{-14}
High-Activity Total	3.96×10^{-3}	5.05×10^{-10}	3.12×10^{-6}	4.00×10^{-14}
TRU Waste:	8.49×10^{-3}	1.74×10^{-10}	6.71×10^{-6}	1.37×10^{-13}
Mixed Waste:	1.08×10^{-1}	1.36×10^{-4}	8.53×10^{-6}	1.07×10^{-7}
Total	1.13×10^2	9.41×10^{-4}	8.85×10^{-2}	7.43×10^{-7}

* Conversion factor = 7.9×10^{-4} LCF/person-rem (BEIR V).

** Based on package dose rate (TI) = 10 as default.

*** Originally treated as high-activity waste but evaluation indicates that material is LLW.

Table E-25. Radiological Transportation Risks for INEL Alternative
Page 1 of 2

Alternative	Dose in Person-rem		LCFs*	
	Incident-Free**	Accident	Incident-Free	Accident
Fresh Prod (2)	7.55×10^1	1.52×10^{-10}	5.97×10^{-2}	1.20×10^{-13}
Fresh Prod (37)	2.83×10^0	1.06×10^{-10}	2.24×10^{-3}	8.37×10^{-14}
Fresh Prod Total	7.83×10^1	2.58×10^{-10}	6.19×10^{-2}	2.04×10^{-13}
Feed:ORNL-Lynch	5.80×10^0	1.47×10^{-8}	4.58×10^{-3}	1.16×10^{-9}
Irrad Prod (2)	3.82×10^1	4.70×10^{-4}	3.02×10^{-2}	3.71×10^{-7}
Irrad Prod (37)	1.43×10^0	3.27×10^{-4}	1.13×10^{-3}	2.59×10^{-7}
Irrad Prod Total	3.96×10^1	7.97×10^{-4}	3.13×10^{-2}	6.3×10^{-7}
Experimental Product	2.90×10^{-1}	4.78×10^{-12}	1.66×10^{-4}	3.78×10^{-15}
Recycle Route 1	4.65×10^{-1}	1.95×10^{-5}	3.68×10^{-4}	1.54×10^{-8}
Recycle Route 2	1.16×10^{-1}	5.69×10^{-5}	9.16×10^{-5}	4.50×10^{-8}
Recycle Route 3	5.81×10^{-1}	2.04×10^{-5}	4.60×10^{-4}	1.61×10^{-8}
Recycle Total	1.16×10^0	9.68×10^{-5}	9.20×10^{-4}	7.65×10^{-8}
LLW:				
Concrete & Steel	1.22×10^0	1.32×10^{-9}	9.64×10^{-4}	1.04×10^{-12}
Aluminum	2.96×10^{-1}	1.17×10^{-11}	2.34×10^{-4}	9.24×10^{-15}
ETS-filters	2.86×10^{-1}	5.05×10^{-10}	2.26×10^{-4}	4.00×10^{-14}
ETS-gravel	2.86×10^{-1}	6.74×10^{-11}	2.26×10^{-4}	5.32×10^{-14}
ETS-silica	2.86×10^{-1}	6.74×10^{-11}	2.26×10^{-4}	5.32×10^{-14}
ETS-struct-1	4.64×10^0	6.31×10^{-8}	3.67×10^{-3}	4.99×10^{-11}
Copper	2.00×10^{-3}	1.33×10^{-8}	1.58×10^{-6}	1.05×10^{-11}
Graphite	2.00×10^{-3}	5.95×10^{-19}	1.58×10^{-6}	4.71×10^{-22}
ETS-struct-2***	1.98×10^{-3}	5.06×10^{-10}	1.56×10^{-6}	4.00×10^{-13}
Beryllium***	2.00×10^{-3}	2.75×10^{-15}	1.58×10^{-6}	2.18×10^{-18}
LLW Total	7.02×10^0	7.78×10^{-8}	5.55×10^{-3}	6.19×10^{-11}

* Conversion factor = 7.9×10^{-4} LCF/person-rem (BEIR V).

** Based on package dose rate (TI) = 10 as default.

*** Originally treated as high-activity waste but evaluation indicates that material is LLW.

Table E-25. Radiological Transportation Risks for INEL Alternative
Page 2 of 2

Alternative	Dose in Person-rem		LCFs*	
	Incident-Free**	Accident	Incident-Free	Accident
High Activity ETS Waste:				
ZiC-Graphite	1.98×10^{-3}	1.60×10^{-13}	1.56×10^{-6}	1.26×10^{-16}
Aluminum	1.98×10^{-3}	5.05×10^{-10}	1.56×10^{-6}	4.00×10^{-14}
High-Activity Total	3.96×10^{-3}	5.05×10^{-10}	3.12×10^{-6}	4.00×10^{-14}
TRU Waste:	1.28×10^{-2}	2.62×10^{-10}	1.01×10^{-6}	2.07×10^{-13}
Mixed Waste:	1.08×10^{-1}	1.36×10^{-4}	8.53×10^{-6}	1.07×10^{-7}
Total	1.32×10^2	1.03×10^{-3}	1.04×10^{-1}	8.14×10^{-7}

* Conversion factor = 7.9×10^{-4} LCF/person-rem (BEIR V).

** Based on package dose rate (TI) = 10 as default.

*** Originally treated as high-activity waste but evaluation indicates that material is LLW.

**Table E-26. Nonradiological Transportation Risks
(fatalities)
Page 1 of 2**

Type	Route	Shipment Number	Fatalities/ One-way trip	Total
Fresh Prod (2) via ALBQ	Lynchburg-NTS	80	4.39×10^{-4}	7.02×10^{-2}
	Lynchburg-INEL	80	5.33×10^{-4}	8.52×10^{-2}
Fresh Prod (37) via ALBQ	Lynchburg-NTS	3	4.39×10^{-4}	2.64×10^{-3}
	Lynchburg-INEL	3	5.33×10^{-4}	3.20×10^{-3}
Feed	ORNL-Lynchburg	50	5.52×10^{-6}	5.52×10^{-3}
Irradiated Product (2) via ALBQ	NTS-Lynchburg	80	4.39×10^{-4}	7.02×10^{-2}
	INEL-Lynchburg	80	5.33×10^{-4}	8.52×10^{-2}
Irradiated Product (37) via ALBQ	NTS-Lynchburg	3	4.39×10^{-4}	2.64×10^{-3}
	INEL-Lynchburg	3	5.33×10^{-4}	3.20×10^{-3}
Experimental Product 4 kg	ALBQ-Lynchburg	1	3.10×10^{-4}	6.20×10^{-4}
Material for Recycle	ALBQ-ORNL	1	2.53×10^{-4}	5.06×10^{-4}
	Lynchburg-ORNL	1	5.52×10^{-6}	1.10×10^{-4}
	ALBQ-Lynchburg	1	3.10×10^{-4}	6.20×10^{-4}
Low Level Wastes:				
Concrete & Steel	NTS-NTS	612	6.80×10^{-6}	8.22×10^{-3}
	INEL-INEL	612	6.80×10^{-6}	8.32×10^{-3}
Aluminum	NTS-NTS	148	6.80×10^{-6}	2.02×10^{-3}
	INEL-INEL	148	6.80×10^{-6}	2.02×10^{-3}
ETS-filters	NTS-NTS	143	6.80×10^{-6}	1.94×10^{-3}
	INEL-INEL	143	6.80×10^{-6}	1.94×10^{-3}
ETS-gravel	NTS-NTS	143	6.80×10^{-6}	1.94×10^{-3}
	INEL-INEL	143	6.80×10^{-6}	1.94×10^{-3}

**Table E-26. Nonradiological Transportation Risks
(fatalities)
Page 2 of 2**

Type	Route	Shipment Number	Fatalities/ One-way trip	Total
Low-Level Wastes (cont'd):				
ETS-silica	NTS-NTS	143	6.80×10^{-6}	1.94×10^{-3}
	INEL-INEL	143	6.80×10^{-6}	1.94×10^{-3}
ETS-struct	NTS-NTS	2319	6.80×10^{-6}	3.16×10^{-2}
	INEL-INEL	2319	6.80×10^{-6}	3.16×10^{-2}
Copper	NTS-NTS	1	6.80×10^{-6}	1.36×10^{-5}
	INEL-INEL	1	6.80×10^{-6}	1.36×10^{-5}
Graphite	NTS-NTS	1	6.80×10^{-6}	1.36×10^{-5}
	INEL-INEL	1	6.80×10^{-6}	1.36×10^{-5}
High-Activity ETS Waste:				
ZiC-Graph	NTS-NTS	1	6.80×10^{-6}	1.36×10^{-5}
	INEL-INEL	1	6.80×10^{-6}	1.36×10^{-5}
Aluminum	NTS-NTS	1	6.80×10^{-6}	1.36×10^{-5}
	INEL-INEL	1	6.80×10^{-6}	1.36×10^{-5}
Structural	NTS-NTS	1	6.80×10^{-6}	1.36×10^{-5}
	INEL-INEL	1	6.80×10^{-6}	1.36×10^{-5}
Beryllium	NTS-NTS	1	6.80×10^{-6}	1.36×10^{-5}
	INEL-INEL	1	6.80×10^{-6}	1.36×10^{-5}
TRU Waste:				
TRU	NTS-WIPP	1	1.85×10^{-4}	3.70×10^{-4}
	INEL-WIPP	1	2.79×10^{-4}	5.58×10^{-4}
Mixed Waste:				
Mixed	NTS-NTS	11	6.80×10^{-6}	1.50×10^{-4}
	INEL-INEL	11	6.80×10^{-6}	1.50×10^{-4}

Table E-27. Total Transportation Risks

Alternative			
Estimated Nonradiological Fatalities			
NTS	0.206		
INEL	0.232		
Estimated Radiological Risk			
	Person-rem	LCFs**	Genetic Effects*
NTS			
Incident-free	1.13×10^2	8.85×10^{-2}	2.94×10^{-2}
Accident	9.41×10^{-4}	7.43×10^{-7}	2.45×10^{-7}
INEL			
Incident-free	1.04×10^2	1.04×10^{-1}	3.43×10^{-2}
Accident	8.14×10^{-3}	8.14×10^{-7}	2.68×10^{-7}

* Based on 2.6×10^{-4} genetic effects/person-rem.

** Latent cancer fatalities.

radius of approximately 130 meters and a temperature of approximately 1,000° K. The hydrodynamic calculation was initialized at this time.

2. The initial velocity field generated by the explosion was ignored. It was assumed that the final rise was governed by the total thermal energy content of the fireball, not its initial distribution.
3. The fuel particles were initially uniformly distributed within the fireball.
4. Fuel particle motion dynamics were similar to those of a sphere 5 millimeters in diameter with a density of 6 grams per cubic meters, respectively. Fluid conditions for the drag equations were obtained from the hydrodynamic solution.

The maximum height of the cloud center of mass was approximately 900 meters and was attained 2 minutes after the detonation. The maximum height obtained by a fuel particle was approximately 3.2 kilometers. The maximum radius was approximately 600 meters.

The settling velocity of the fuel particles is approximately 5 meters per second. Assuming downwind transport of 5.5 meters per second and free fall conditions subsequent to the rise (no turbulence effects), the footprint dimensions are estimated as:

center of mass range:	1.6 kilometers
maximum range:	5.2 kilometers
maximum width:	1.2 kilometers

Since the center of mass radius is considerably less than the maximum, the distribution of the fuel particles within the footprint is expected to be peaked in the crosswind direction.

The above analysis provides a rough estimate of the fuel particle footprint resulting from a hydrogen explosion and should not be given undue credit. The significant result is that the winds subsequent to a hydrogen explosion are sufficient to loft fuel particles if they somehow become entrained in the flow. The contamination from such an accident is expected to remain on station.

4.2 CONTAMINATION CONSEQUENCES

Calculations have been performed to determine the effective dose equivalent from soil contamination assuming the entire source term is placed on the ground. These calculations have been done following guidance in DOE Order 5400.5, Chapter 4, where the effective dose equivalent limit from soil contamination is given as 100 mrem/year. If the effective dose

from soil contamination is less than this value, no restriction is placed on the land. Two pathways have been included in the dose calculations: direct dose from soil contamination and dose from resuspension inhalation. The ingestion pathway has not been included in this analysis, since it is highly unlikely that anyone will be permitted to farm and live on either the SMTS or CTF sites in the foreseeable (50 years) future. Should a major accident occur, this may require long-term restrictions on some land now open (under permit) for grazing at INEL. Due to these restrictions, the doses from these calculations represent on-site worker doses if workers are allowed to stay on contaminated ground.

The maximum credible accident that resulted in the greatest consequences to the public and on-site workers was primarily an airborne gaseous release. This would not result in significant ground contamination. A Consequence I type accident would result in the greatest amount of ground contamination but no mechanism to achieve such a 100 percent release could be identified. Although such an accident is not credible, it is presented as the maximum hypothetical ground contamination impact. Results of a 5 percent release are also presented. While a 5 percent value is expected to be a conservative overestimate of consequences, it comes closer to a credible estimate. The calculation of effective dose equivalents from ground contamination for these source terms includes both noble gases and particulate matter. This is conservative in that noble gases will actually be carried away rather than deposited on the ground. Results of this analysis have been used to determine the length of time following release in which dose rates exceed 100 mrem per year. These results are presented in Table E-28.

Table E-28. Effective Restricted Use Time (years)

Area (km ²)	Consequence I	5% Consequence I
1	> 50.0	9.8
10	34.0	5.0
100	7.4	0.73
1,000	0.84	0.10
10,000	0.35	< 8 hours

In the case of ground contamination, the results of these calculations can be used to assess whether cleanup is necessary or whether the land can be fenced and posted and the activity allowed to decay to acceptable levels. Note that no ground contamination is expected as a result of normal operations, rather, the consequences described here are the result of a

beyond maximum case accident. Actual accident impacts can be expected to be much smaller.

5.0 BOUNDING ENERGETIC ACCIDENT

5.1 INTRODUCTION

The accident which would result in the largest energy release in the form of a blast wave involves the combustion of hydrogen stored on station. Liquid and gaseous hydrogen are used as both a working fluid for the SNTP system and as a coolant for the ETS. The amount of hydrogen stored on station will depend on the final configuration of the test apparatus. The current estimate for the ground test article (GTA) is 1.76×10^6 kilograms, with approximately 95 percent being stored in liquid form. The largest container type is expected to be a 1.27×10^4 kilograms (50,000 gallons) cryogenic vessel. An energetic release can produce both fragments and blast overpressure. It is anticipated that due to the large amount of hydrogen on station that blast overpressure represents the most serious consequences of an energetic event.

For the purpose of determining the consequences of an energetic event, both SMTS, and CTF are sufficiently similar that they can be treated as the same except where noted. Using the U.S. Standard Atmosphere (The U.S. Standard Atmosphere, 1962) pressures for altitude, the average pressure is 84.5 kilopascals (kPa). In general, SMTS at the Nevada Test Site is warmer than the INEL particularly in the winter. Using the Standard Atmosphere temperatures, the temperature corresponding to 84.5 kPa is 278 degrees Kelvin (K). This temperature is consistent with winter temperatures at SMTS and spring/fall temperatures at the INEL. For this analysis, the pressure is taken as 84.5 kPa and the temperature as 278 K.

The consequences of an energetic event will be somewhat affected by terrain. The SMTS facility differs from the CTF facility in that SMTS resides in a valley. For blast overpressures, the pressures will be higher on the sides of mountains facing the blast and lower on the sides of mountains facing away from the blast compared with a flat terrain. Studies of acoustic attenuation shows that lower overpressures exist behind barriers extending horizontally about ten barrier heights (Keefer and Day, 1966). Beyond this shadow zone, the overpressures return to that predicted for a flat surface. For this analysis, terrain effects will be ignored at all three sites and a flat surface will be assumed to extend in all directions from the site out to the radius in which there are no longer any consequences from blast overpressure.

5.2 ACCIDENTS

Accidents that could result in hydrogen combustion can be initiated in a number of ways. Both external events, such as a aircraft strike, or internal events, such as an unintentional release can result in the formation of a hydrogen cloud. In general, hydrogen is lighter than air and will rise away from the source. As such, it is much safer than hydrocarbon gases such as gasoline vapor. However, cryogenic hydrogen is heavier than air until it warms sufficiently. If hydrogen is released, it will mix with the surrounding air. The details of the evolution and mixing process are complex and accident dependent. For this analysis, a cloud is assumed to form along the ground in a cylindrical shape with a radius 5 times the height. The size of the cloud depends on the amount of hydrogen, and will tend to rise on warming. However, from a consequence point of view, the worst case is the formation of a uniform cloud that is stoichiometric, i.e., two parts hydrogen for every part oxygen. For this analysis, it is assumed that a uniform, stoichiometric cloud forms.

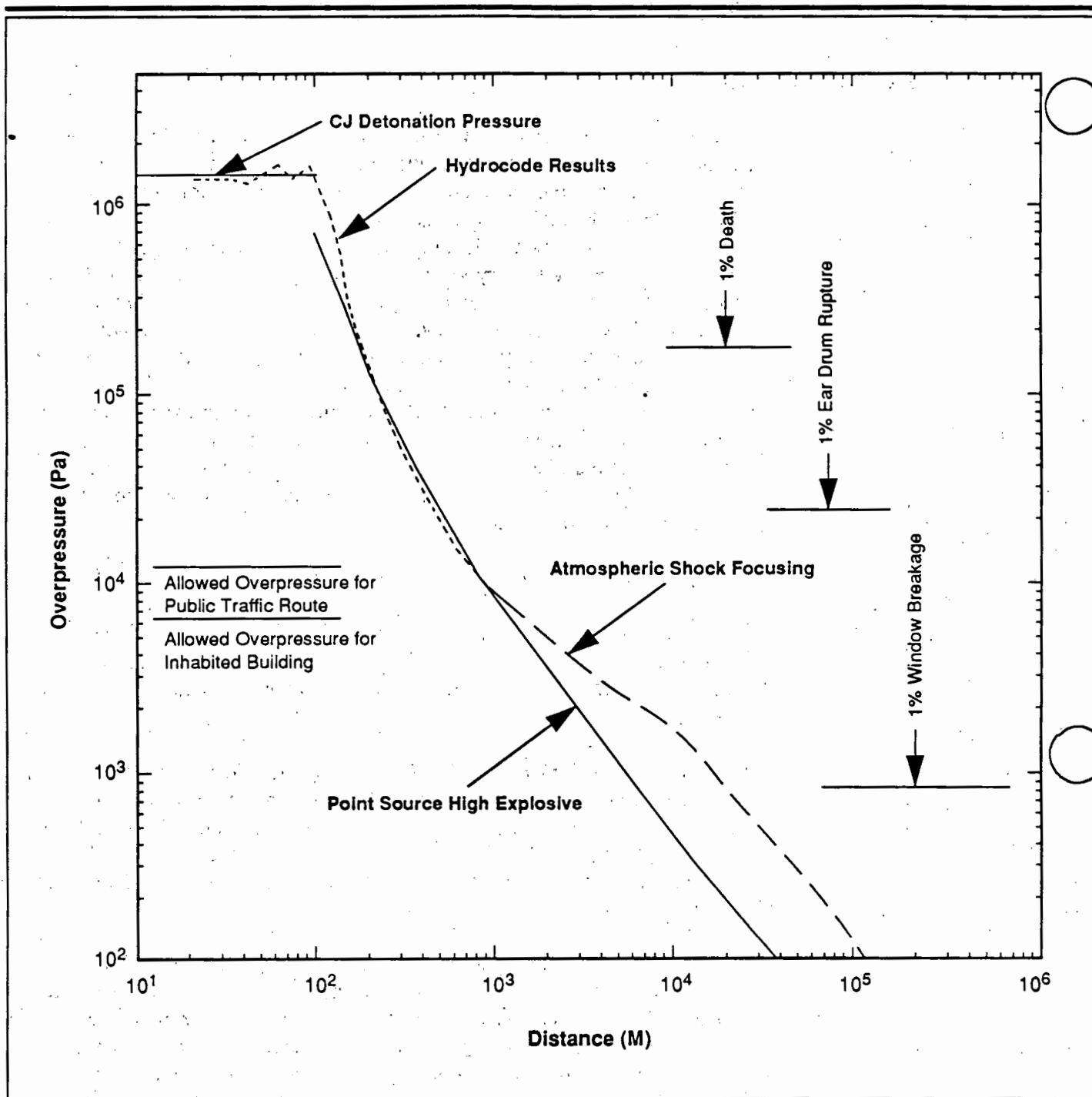
If an ignition source is present in a flammable mixture (Kumar, 1985), then combustion will result. The worst case situation from a consequence point of view is if the mode of combustion is detonation. A detonation will convert the highest fraction of chemical energy to directed kinetic energy (blast overpressure). For this analysis, it is assumed that the cloud detonates.

Two cases will be considered. The first case is the failure of a single vessel and the subsequent detonation of the cloud. This accident is considered credible but the analysis is an upper bound for the accident. The resulting overpressures will very likely be lower than those presented below. For this case, the hydrogen-air cloud is 20 meters high with a radius of 100 meters and is centrally initiated.

The second case is a common mode failure of all vessels and subsequent detonation of all hydrogen on station. This accident is considered incredible and is included only because it represents an absolute upper bound on the energetic release from a hydrogen combustion accident. For stoichiometric conditions, the resultant cloud would have a radius of 235 meters and be 47 meters high. An accident initiator sufficiently large to cause common mode failure will almost certainly ignite the mixture before it has time to mix to conditions in which a detonation can occur and be sustained.

5.3 BLAST OVERPRESSURE MODELS

Figure E-2 shows the overpressure as a function of distance for a single dewar accident. Four models were used to generate the curves shown. The first model is the Chapman-Jouguet (CJ) detonation model. The second model is a hydrocode calculation of a detonating hydrogen-air cloud. The



Overpressure vs. Distance

Note: Detonation of 12,700 kg of hydrogen in air. Cloud is axisymmetric with a 100 m radius and a 20 m height and is a mixture of stoichiometric hydrogen/air. The ambient temperature is 278 K and the ambient pressure is 84.5 kPa. The overpressure is the incident or "side-on" overpressure. The allowable overpressure levels for public traffic and inhabited buildings are based on DOD standard 6055.9 requirements.

Figure E-2

third is a point-source blast (high explosive) model and the fourth is a correlation of atmospheric focusing (caustics) effects. The "side-on" pressure for a detonation wave is given by the CJ pressure (Strehlow, 1984). For this analysis the CJ pressure is 1.4116 MPa as calculated by the McBride code (McBride, 1989).

The hydrocode model used is CTH (McGlaun and Thompson, 1990). The detonation in the cloud is modeled as a CJ detonation. The air is modeled as an ideal gas. No gradients existed in the cloud or the air. The computational grid is axisymmetric, 100 by 400 nodes. The results have been adjusted to match the CJ pressure in the cloud.

For radii farther than a few cloud diameters, the energy release from the gaseous detonation can (to a first order) be approximated as a point-source high explosive of the same energy content. Using a value of 120 MJ/kg for the heat of combustion of hydrogen and a value of 4.27 MJ/kg for a heat of detonation for TNT, the amount of TNT required to produce the same blast energy as hydrogen is 28:1. For the single dewar failure, this amounts to 3.55×10^5 kilograms (approximately 5.4 kilotons) TNT equivalent. Standard overpressure vs. distance curves are available for blast overpressure from a surface burst of TNT. The curves can be scaled to the amount of high explosive by the (charge weight)^{1/3} scaling law (Baker, 1983). For this analysis, the point-source curve in Figure E-2 was calculated with the BLASTO (Reed, 1988) code.

Finally, atmospheric effects can increase the blast overpressure in the far field. The worst case effect is that of atmospheric focusing. Due to changes in sound speed with temperature, variations in temperature with altitude can result in caustics (focused shock waves) (Reed, 1987, 1988). Caustics can cause a three to five fold increase in the expected pressure. For this analysis, the caustic effects are also calculated with the BLASTO (Reed, 1988) code.

5.4 CONSEQUENCES

Figure E-2 shows the overpressure levels corresponding with different levels of damage. The 1 percent mortality and 1 percent ear drum rupture levels are taken from DOD 6055.9-STD (Assistant Secretary of Defense, 1991) and are 186 kPa (50 millisecond duration) and 23.4 kPa, respectively. The 1 percent window breakage is taken from Reed (1987) and is 0.9 kPa. Also shown in Figure E-2 are the allowable levels for public traffic routes and inhabited buildings. These values are taken from DOD 6055.9-STD (Assistant Secretary of Defense, 1991) and are 11.7 kPa and 6.2 kPa, respectively.

Table E-29 gives the distances to the various threshold levels for the single dewar accident. Using the standard one-third power scaling law, the

Table E-29. Damage Distances from Single Dewar Accident

Threshold	Distance (kilometers)
1% Window Breakage	19.5
Safe Inhabited Building Distance	1.5
Safe Public Road Distance	0.825
1% Ear Drum Rupture	0.525
1% Death	0.2

distances for the detonation of all hydrogen on station is 2.4 times the values listed in Table E-29.

In summary for the single dewar accident, the onstation consequences for both SMTS and CTF include injury and death for all unprotected personnel and structural damage to the facility. On-site but offstation consequences for all three potential stations include possible minor structural damage (window breakage). For SMTS, there are no off-site consequences as the nearest public boundary is 23 kilometers, beyond the 19.5 kilometers predicted damage distance. For CTF some window breakage is possible off site due to the shorter public boundary distance (13 kilometers).

6.0 ANALYSIS OF ACCIDENT-CASE BERYLLIUM RELEASE

The PIPET and GTA assemblies contain beryllium metal which may become airborne in a catastrophic failure. In the event of an accident in which core integrity is lost (see Section 2.4), there is the potential for some or all of this beryllium to be released. Since oxidized respirable beryllium is considered a toxic material, its impact on the public must be considered. At this time there is no credible accident case which can be identified in which significant amounts of beryllium can be mobilized; however, in order to determine a conservative evaluation of potential impacts, an analysis using complete beryllium dispersal was performed.

The release data for determining beryllium inhalation was taken from SNL engineering estimates. The estimate of beryllium available for release is approximately 44 pounds for PIPET and 220 for the GTA test systems (Hipp, 1991). These amounts were assumed to be fully aerosolized in a maximum-case accident and subsequently dispersed into the resulting plume.

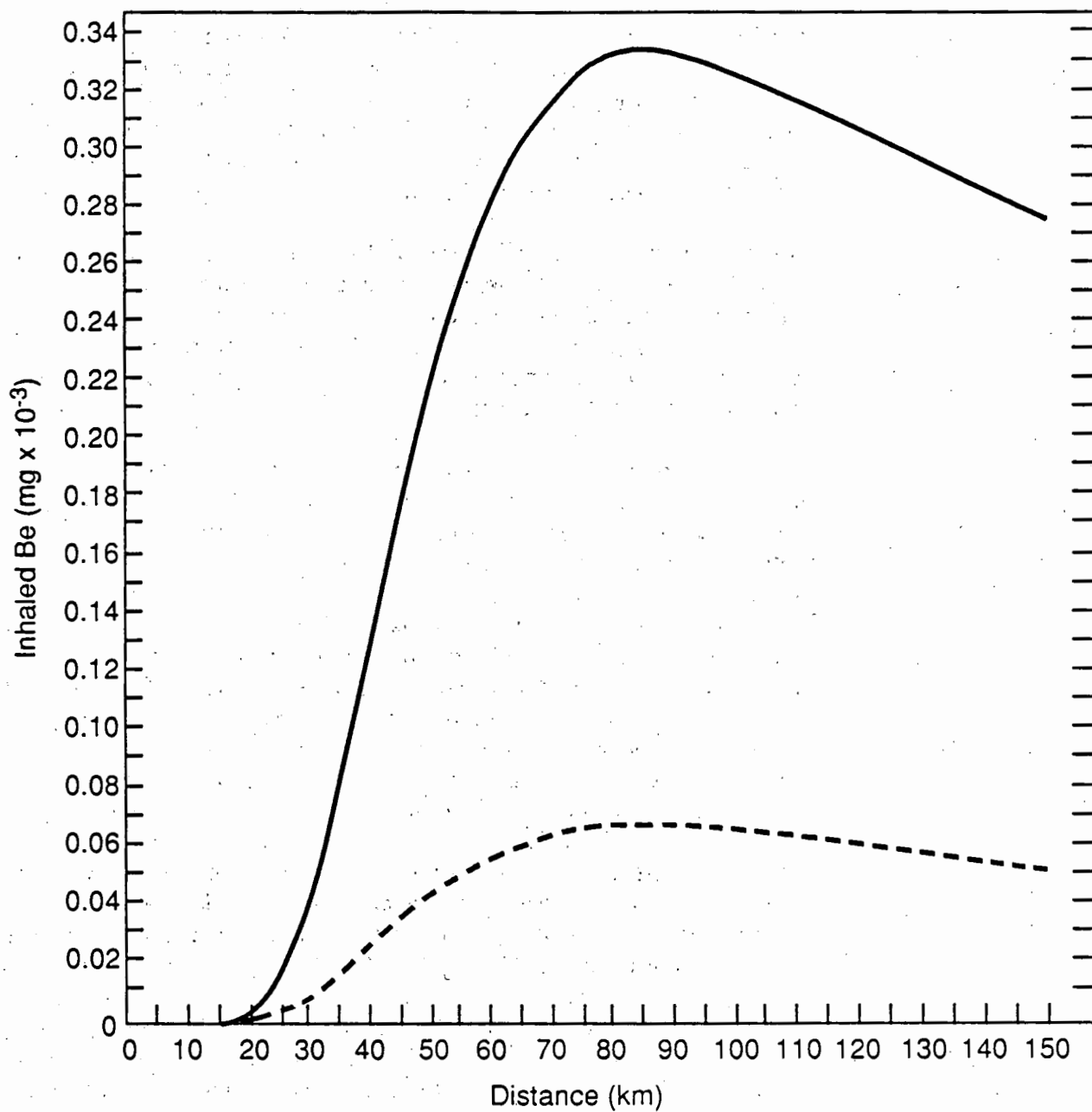
The aerosolized beryllium dispersion was modeled using the MACCS plume release model. The MACCS code provides information concerning the total amount of airborne particulates to which a person may be exposed (time integrated ground-level air concentration data) at any distance downwind of

the release point. The amount of beryllium inhaled is determined by multiplying the time-integrated ground-level beryllium air concentration by the typical human breathing rate (3.47×10^{-4} cubic meters per second). The peak concentration of the beryllium cloud at the point of maximum inhalation is shown in Figure E-3 as well as concentrations at all locations directly downwind (referred to as the "centerline").

Additional beryllium may be located in the axial core reflectors; however, analysis of the proposed core designs indicates that this material is sufficiently removed from any potential heat sources and that volatilization as an aerosol is not possible. This material may be distributed in large fragments within the immediate vicinity of the accident site, but would not constitute an inhalation hazard (Hipp, 1991).

OSHA has developed standards for the occupational exposure of workers to beryllium. These are determined using toxicological and past exposure history data to arrive at total exposure (amount of beryllium inhaled) to which an occupationally exposed person may be exposed on a daily basis without suffering any harmful effects. The allowable exposure incorporates safety factors to account for sensitive individuals, as well as adequate safety margins, and therefore does not represent an absolute threshold value above which effects will be observed. Rather, it can be expected that for most individuals, it would require a considerably higher single-day exposure to produce any noticeable effect. The maximum daily exposure to beryllium which has been accepted by OSHA is 0.0173 milligrams. Using this as a starting point, a value for allowable airborne concentrations is calculated (again using the above breathing rate of 3.47×10^{-4} cubic meters per second) based upon an exposure time of 8 hours per day (a typical work day). This calculated value, which is expressed in milligrams of beryllium per cubic meter of breathing air (mg/m^3), is referred to as the Permissible Exposure Limit (PEL), and has a value of $0.002 \text{ mg}/\text{m}^3$. Since exposure to beryllium may also induce immediate harmful effects in cases of extremely high concentrations, OSHA has also adopted a value of $0.025 \text{ mg}/\text{m}^3$ as the highest allowable airborne concentration to which a worker may ever be exposed, without consideration of exposure time or total dose received.

A GTA release, which is the maximum-case beryllium release, would result in a maximum total exposure (through inhalation) of approximately 0.00033 mg, which is over 50 times lower than 0.0173 mg value adopted by OSHA for total daily exposure. Furthermore, a maximum airborne concentration of $0.016 \text{ mg}/\text{m}^3$ is calculated for a GTA accident release, which is almost a factor of two lower than the OSHA peak concentration limit of $0.025 \text{ mg}/\text{m}^3$. Beryllium exposures from the postulated PIPET accident would be approximately 20 percent of GTA values (see Figure E-3).



EXPLANATION

- GTA Release
----- PIPET Release

**Beryllium Inhalation
as a Function of
Distance**

Figure E-3

7.0 REFERENCES

- Assistant Secretary of Defense (Force Management and Personnel), 1991. Ammunition and Explosives Safety Standards, DoD 6055.9-STD Change 3, Department of Defense, Washington, DC, January.
- Baker, W.E., 1983. Explosives in Air, published by Wilfred Baker Engineering, San Antonio, Texas
- Bonzon, L.L., 1977. Final Report on Special Impact Tests of Plutonium Shipping Containers, Description of Test Results, SAND76-0437, Sandia National Laboratories, Albuquerque, New Mexico.
- Carney, T., 1992. Memo from T. Carney (ASI) to W.H. McCulloch (Sandia) regarding: Energetic Plume Rise Estimates, May 12.
- Cashwell, J. W., 1987. "TRANSNET - A User Network of Transportation Analysis Model," Waste Management 87.
- Clawson, K.L., et al., 1989. Climatology of the Idaho National Engineering Laboratory, second edition, DOE/ID-12118, December.
- Fischer, L.E., et al., 1987. Shipping Container Response to Severe Highway and Railway Accident Conditions, NUREG/CR-4829, UCID-20733, Nuclear Regulatory Commission, Washington, DC, February.
- International Commission on Radiological Protection, 1979. Limits for Intakes of Radionuclides by Workers, ICRP Publication 30, Pergamon Press, New York.
- Kasperson, R.E., O. Renn, P. Slovic, H.S. Brown, J. Emel, R. Goble, J.X. Kasperson, and S. Ratick, 1988. "The Social Amplification of Risk: A Conceptual Framework," Risk Analysis, Vol. 8, Number 2, 1988.
- Keefer, J.H., and J.D. Day, 1966. Terrain Effects on Blast Wave Parameters, BRL-1319, U.S. Army Ballistic Research Laboratories, Aberdeen, Maryland, April.
- Kumar, R.K., 1985. Flammability Limits of Hydrogen-Oxygen-Diluent Mixtures, Journal of Fire Sciences, 3:245-262.
- Leppert, J.L., 1992. Informal communication regarding: 1990 Population Census Data for Census Data for Selected Areas Surrounding NTS, Chief Project Engineering Branch, Engineering and Energy Management Division, USDOE/NV, April 22.
- McBride, B., 1989. CT89 - Chemical Equilibrium with Transport Properties, NASA Lewis Research Center.

- McGlaun, J.M., and S.L. Thompson, 1990. CTH: A Three-Dimensional Shock Wave Physics Code, International Journal of Impact Engineering, 10:351-360.
- Mulryan, D. 1987. Personal communications with S. Neuhauser, Sandia National Laboratories, September 2.
- National Aeronautics and Space Administration, 1968. Hydrogen Safety Manual, Advisory Panel on Experimental Fluids and Gases, NASA TM X-52454, LERC.
- Neuhauser, K.S., and P.C. Reardon, 1986. A Demonstration Sensitivity Analysis for RADTRAN III, SAND85-1001, Sandia National Laboratories, Albuquerque, New Mexico, October.
- Neuhauser, K.S., and F.L. Kanipe, 1991. RADTRAN 4, Executive Summary, SAND91-0776, (in preparation).
- Nuclear Regulatory Commission, U.S., 1977. The Transportation of Radioactive Material by Air and Other Modes Final Environmental Impact Statement, December.
- Ostmeyer, R.M., 1986. An Approach to Estimating Food Ingestion Exposures for Nuclear Transportation Accidents, SAND85-1722, Sandia National Laboratories, Albuquerque, New Mexico.
- Quiring, R.F., 1973. Summary of Inversion Statistics, ARLV-351-37, NOAA.
- Rao, R.K., E.L. Wilmot, and P.E. Luna, 1981. Nonradiological Impacts of Transportation Radioactive Material, SAND81-1703, Sandia National Laboratories, Albuquerque, New Mexico.
- Reed, J.W., 1987. Climatological Assessment of Explosion Airblast Propagations, SAND86-2180C, Sandia National Laboratories, Albuquerque, New Mexico.
- Reed, J.W., 1988, Explosion Airblast Predictions on a Personal Computer and Application to the Henderson, Nevada, Incident, SAND88-0681 C, Sandia National Laboratories, Albuquerque, New Mexico.
- Sandia National Laboratories, 1976. Safety Analysis Report for Safe-Secure Trailer (SST-2), Albuquerque, New Mexico (Classified Report).
- Sherman, M.P., 1991. Memos from M.P. Sherman, Sandia, to R.L. Coats, Sandia, regarding: Vented Bottle Model, March-April.
- Smith, R.N., and E.L. Wilmot, 1982. Truck Accident and Fatality Rates Calculated for California Highway Accident Statistics for 1980 and 1981, SAND82-7066, Sandia National Laboratories, Albuquerque, New Mexico.
- Strehlow, R.A., 1984. Combustion Fundamentals, McGraw Hill.

The U.S. Standard Atmosphere, 1962. U.S. Government Printing Office, Washington, DC.

Wolff, T.A., 1984. The Transportation of Nuclear Materials, SAND84-0062, Sandia National Laboratories, Albuquerque, New Mexico, December.

Young, M.F., 1992. Memos from M.F. Young, Sandia, to W.H. McCulloch, Sandia, regarding The Expected Fission Product Release From the PIPET and GTA Normal II Experiments, May 7 and May 28.

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APPENDIX F
SITE NARROWING REPORT SUMMARY

APPENDIX F SITE NARROWING REPORT

Summary

The site narrowing report documents the process, rationale, and results of the siting methodology used to narrow the location of the Test Program from multiple sites throughout the Continental United States (CONUS) to three sites. The ultimate site selection decision will be based on the siting report, the EIS, and other program documents.

A systematic, multidisciplinary approach was implemented to incorporate all technical, operational, policy, and legal factors into the siting process and to achieve four basic goals: (1) maximize project effectiveness by maximizing project security, optimizing site operations, and maximizing mission compatibility; (2) minimize cost through maximizing constructability and minimizing construction requirements; (3) minimize public impacts by minimizing economic impacts and maximizing public safety, and (4) minimize environmental impacts through minimizing impacts to the natural and cultural resources and to special status lands.

The site selection process established to achieve these goals was based on the application of exclusionary and evaluative criteria. Exclusionary criteria define the minimum level of acceptability of alternative sites. Evaluation criteria did not exclude sites, but were developed to measure preferences for specific site characteristics. All of these criteria are presented in the Final Site Narrowing Report (THG, 1991).

Exclusionary Criteria

Initial screening began with the application of the exclusionary criteria which required that the site be a federally owned facility and be located within the Continental United States (CONUS). In addition, sites were screened for similarity of operations. Specifically, sites were excluded if they did not currently host similar nuclear research operations and have the infrastructure to support defense-related nuclear research activities. It was at this point that several Department of Defense (DOD) sites were dropped from the list, leaving thirteen Department of Energy (DOE) sites for further consideration.

The second step in the narrowing process involved the application of the "stand-off" requirement that required that the site be at least 15 KM (9.3 miles) from the nearest urban area as measured on a U.S. Geologic Survey (USGS) 1:100,000 scale map. This eliminated all but the four sites of Hanford, Idaho National Engineering Laboratory (INEL), Nevada Test Site (NTS), and the Savannah River Site (SRS).

DOE determined that the proposed test program created a significant conflict with the Hanford and Savannah River operations (THG, 1991). Savannah River is currently the primary source for tritium production in the United States. In order to maintain ample separation between and tritium production activities, siting the test facility at Savannah River would conflict with wetlands and special status lands on the installation as well as the use of public roads that cross SRS. Hanford was excluded because it is currently undergoing environmental restoration as a requirement of a memorandum of agreement with the State of Washington. The ground testing program is not compatible with this agreement or the restoration activities. Also the public attention that Hanford has received recently regarding the environmental restoration program is inconsistent with the program security requirements.

Following the application of the exclusionary criteria and the discussions with DOE regarding Hanford and Savannah River conflict issues, the process of applying the evaluative criteria to the two remaining installations, NTS and INEL, began.

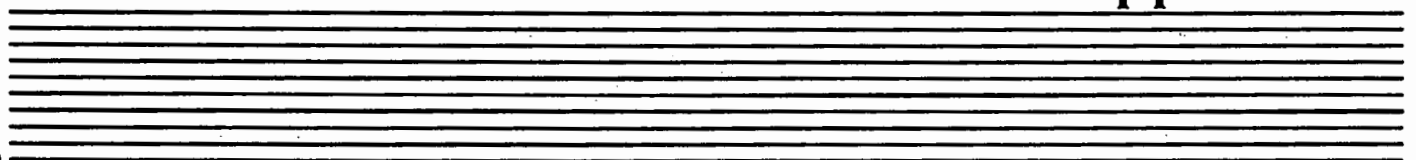
Evaluative Criteria

A team consisting of government and contractor experts in safety, security, program technology, and civil and environmental engineering was formed to apply the evaluative criteria to identify specific alternative sites at NTS and INEL. This team met with installation representatives who were familiar with operations, land use, and other concerns at the installations. Discussions with these representatives placed particular emphasis on ongoing and planned land use in the immediate area of any potential alternative site which might be considered.

Based on the requirements of the program and the knowledge of the installation representatives, three specific sites were identified for further evaluation. These included the Saddle Mountain Test Station (SMTS) at NTS and the QUEST and LOFT sites at INEL. Tours of the installations were conducted and specific site visits were made to SMTS and LOFT. Sufficient characterization of the QUEST site was possible with a reconnaissance of the areas surrounding the site and published information.

The ultimate site selection decision will be based on the siting report, the EIS, and other program documents.

Appendix G



APPENDIX G
CULTURAL RESOURCES

ARCHAEOLOGICAL AND HISTORIC SURVEY REPORT

IDAHO ARCHAEOLOGICAL SURVEY

A. Project Name and Statement of Objectives

Project Name: Cultural Resources Investigation - Idaho National Engineering Laboratories (INEL) - Containment Test Facility Site (CTF) (also known as Loss-of-Fluid Test Site [LOFT]) and QUEST Site

Objective: To evaluate the significance of cultural resources within the area of potential effect (APE) for both alternatives at the INEL, assess direct and indirect impacts to any identified resources, and recommend appropriate mitigation measures to be incorporated into the Environmental Impact Statement

B. Name and Full Description of the Proposed Undertaking

Name: Space Nuclear Thermal Propulsion Program - Environmental Impact Statement

Description of the Proposed Undertaking: The Department of the Air Force and the Department of Energy propose to validate the technology of a particle bed reactor propulsion system. Validation of this technology may open doors in the areas of space travel, power generation, and disposal of nuclear waste. Two locations at the Idaho National Engineering Laboratory, the CTF and the Quest sites, were selected early in the site narrowing process as reasonable alternatives for ground test activities (Figures 1, 2, 3, and 4). Since that time, the QUEST site has been eliminated from consideration as an alternative, because of the presence of significant cultural resources identified during the environmental process. Because cultural resources field work has already been initiated for the QUEST site, this survey report will include that data, even though the site is no longer considered an alternative for the SNTP program.

Selection of the CTF alternative would require modification of existing facilities and the construction of a hydrogen tank farm. Selection of the QUEST alternative would have required construction of all facilities, roads, and infrastructure. Direct impacts from SNTP program activities would include those associated with above and below ground construction and from facility remodeling.

Indirect impacts could result from increased personnel and vehicular use of sensitive areas, erosion, and the potential for unauthorized artifact collection and vandalism.

C. Location and General Environmental Setting

INEL lies within the Snake River Plain of southern Idaho adjacent to the foothills of the Lemhi, Lost River, and Bitterroot Mountain ranges. Archaeological and paleontological investigations of the Snake River Plain have identified several sites significant in North American prehistory, including Wilson Butte Cave (southwest of the INEL), the Wasden Site/Owl Cave (just east of the INEL), and the Birch Creek Sites/Bison and Veratic Rockshelters (north of the INEL). Intensive survey and test excavation within the INEL boundaries has also contributed to a greater understanding of this region, which spans a period of time that covers 12,000-15,000 years. To date, over 1000 sites have been recorded on the INEL with only three percent of the total 890 square miles of the installation surveyed.

Paleontological resources have been identified throughout the INEL, as well. Sites appear in lava tubes, rockshelters, caves, packrat middens, and alluvium, and reflect the remains of extinct animals such as the camel, mammoth, and North American horse.

CTF Alternative

The CTF site at INEL is located in a portion of Test Area North (TAN) located in the northern part of the installation, near the western margin of the Birch Creek playa (see Figures 1 and 2). Existing facilities, paved roads, and infrastructure to support the SNTP program are already located at this location and the entire facility area has been previously disturbed through grading and construction, including raising the surface of the site with fill pads by about 15 feet.

U.S.G.S. Topographic Map: Circular Butte, Idaho

Boundary of Sections 11 and 12 - Township 6 North, Range 31 East

QUEST Alternative

The QUEST site at INEL is located in the east central portion of the installation (see Figures 1, 3, and 4). It is located in an undeveloped area that contains a ridge which rises approximately 50-100 feet above adjacent plains and marks the forward margin of a single

basalt flow; surficial soils are present in varying depths. The site is accessed only from the north and south along a narrow, rutted, and rocky road that was built to access an overhead transmission line. All of the facilities and infrastructure would have to be constructed for the SNTP program at this site (approximately 200 acres) and the main access road would have to be improved.

U.S.G.S. Topographic Map: Little Butte NW, Idaho
Sections 11, 12, 13, 15 - Township 4 North, Range 32 East

D. Pre-Field Research

1. Sources of information checked:

- [X] Overviews
- [X] Site Sensitivity Maps at EG&G Idaho, Inc.
- [X] Other

EG&G Idaho, Inc., no date. LOFT (Loss of Fluid Test), Idaho Operation Office.

Idaho National Engineering Laboratory, 1986a. Idaho National Engineering Laboratory, History of Facilities and Programs.

Idaho National Engineering Laboratory, 1986b. Idaho National Engineering Laboratory Annual Report.

Idaho State University, 1986. Archaeological Investigations on the Idaho National Engineering Laboratory 1984-1985, August.

Idaho State University, 1987. Archaeological and Paleontological Survey of the INEL for the SSC NEPA Compliance Plan, December.

Smithsonian Institution, 1986. Handbook of North American Indians, Washington D.C., Volume 11, Great Basin.

U.S. Department of Energy, Idaho Operations Office, no date. The OECD LOFT Project.

U.S. Department of the Interior, National Park Service, 1991. National Register Bulletin 15.

Walker, D. E., 1978. Indians of Idaho, University of Idaho Press, Moscow, Idaho.

2. Summary of previous studies in this general area:

CTF Area of Potential Effect

Several areas associated with the TAN facility, which includes the CTF, were examined between 1982 and 1985 as a part of a program designed to identify cultural resources in danger of being disturbed through increased installation activities on the INEL (Idaho State University, 1986). In July 1985, an archaeological/paleontological survey of a 100-meter-wide zone (328 feet) surrounding the CTF facility was conducted by EG&G; one sparse lithic scatter (10-BT-1234) and one isolated activity area (10-BT-1235) were recorded during this survey; neither was considered of sufficient significance to be potentially eligible for the National Register (Idaho State University, 1986). While fossil camel remains have been identified in the vicinity of the TAN facility, no paleontological resources have been recorded or identified in the CTF site area.

Quest Area of Potential Effect

Reconnaissance-level survey was accomplished in 1992 by EG&G archaeologists at the primary site of construction for SNTP Program activities and intensive surveys were completed in 1985 by EG&G for a grazing boundary and along the road which accesses QUEST site from the Argonne National Laboratory-West (ANL-W) to the south (Idaho State University, 1986). Site types include hunting locations, field camps where game processing occurred, and tool modification areas; some of these sites are potentially eligible for the National Register. No paleontological remains have been confirmed within the APE for the QUEST site. However, an extensive packrat midden, similar to those which typically have the potential to yield such resources, is located within the talus of the lava flow.

E. Expected Historic and Prehistoric Land Use and Site Sensitivity

CTF Alternative

1. Are there sites known in this area? ☒ Yes ☐ No
2. Are sites expected? ☐ Yes ☒ No

Previous surveys of the area surrounding the TAN/CTF facilities indicate a low probability for encountering additional cultural

resources (Idaho State University 1986). Consultation with INEL's cultural resources contractor, EG&G, confirmed that no further archaeological surveys would be required for SNTP Program activities at the CTF site.

QUEST Alternative

1. Are there sites known in this area? ☒ Yes ☐ No
2. Are sites expected? ☒ Yes ☐ No

Previous intensive archaeological survey and reconnaissance performed by EG & G archaeologists indicates a high degree of archaeological sensitivity in the QUEST ridge area (see Figure 3). The current level of survey has recorded over 50 sites within this region representing a density of approximately four sites per linear mile and indicating the highest site density encountered to date on the INEL (Idaho State University, 1986). Some of the sites located along the access road between ANL-W and the QUEST site are believed to be potentially eligible to the National Register.

F. Field Methods

1. Areas examined and type of coverage:

CTF Alternative (see Figure 2)

Intensive survey by EG&G in 1985

QUEST Alternative (see Figure 3)

Reconnaissance by EG&G in 1985 and 1992

Reconnaissance by The Earth Technology Corporation, accompanied by EG&G, in 1992

2. Surface and subsurface visibility:

CTF Alternative

The CTF APE is partially covered by existing facilities, paved roads, and parking lots (30 percent); vegetative cover in open spaces is sparse to non-existent.

QUEST Alternative

Because the QUEST site is partially located within a lava flow, much of the surface is basalt covered (60 percent); plains adjacent to the flow are covered by moderate to sparse vegetation (40 percent).

3. Acres Surveyed

QUEST Alternative

Reconnaissance: Approximately 400 acres in early 1992 (EG&G)
Approximately 200 acres in April 1992 (TETC
accompanied by EG&G)

4. Areas not examined and reasons why:

CTF site - surveyed in 1985 - (see Figure 2)

Access road from Argonne Lab past the Quest site and ending near
the southern boundary of Section 26 - surveyed in 1985 - (see
Figures 3 and 4)

5. Personnel conducting or assisting in the survey:

The Earth Technology Corporation

Paige Peyton, Field Director

Senior Project Environmental Specialist in Cultural Resources

Paul Titus

Project Environmental Specialist in Cultural Resources

Peter Xander

Senior Project Environmental Specialist in Biological Resources

Brian Mayerle

Staff Ecologist

EG&G

Clayton Marler, Archaeologist

Brenda Ringe, Archaeologist

Tim Reynolds, Biologist

6. Dates of Survey:

April 14-15, 1992

7. Problems Encountered:

See "G." below.

G. Results

1. Cultural resources noted but not formally recorded

Survey of the QUEST site APE was performed by Air Force contractor archaeologists (Earth Technology) in April 1992, accompanied by EG&G archaeologists familiar with the region. Because of the topography and the extent and complexity of the primary site (previously identified and recorded as EGG-92-2-1), traditional survey techniques (systematic transects and mapping) were abandoned and organized reconnaissance was employed. Site edges could not be accurately determined and are felt to extend well beyond the APE for SNTP Program construction activities in all directions, particularly north and south along the ridge line. Diagnostic projectile points were scant, but those that were present indicate a period of occupation that covers approximately 7500 years. Because of the depth of surficial soils noted throughout the APE and the high winds common to the area, the potential for buried resources exists and the currently estimated time frame for occupation may increase. The site is an extensive scattering of lithic and ceramic materials with features that include hearths and associated fire-cracked rock; pottery sherds; burned bone/tooth enamel fragments associated with lithic materials; an extensive packrat midden; and chinked stone walls of undetermined purpose which are unique on the INEL. In addition to ignimbrite, at least ten exotic source materials were identified (e.g., obsidian, assorted colors of cryptocrystallines, fine-grained basalts, and rhyolite). No rock art, rock shelters, lava tubes, or confirmed evidence of pleistocene megafauna were noted. Except for the area immediately surrounding the QUEST benchmark and disturbance caused by traffic along the power line access road, the entire QUEST site APE remains undisturbed. No cultural materials were collected during the survey.

H. Conclusions and Recommendations

CTF Alternative

Two prehistoric archaeological sites (one sparse lithic scatter [10-BT-1234] and one isolated activity area [10-BT-1235] have the potential to be effected by SNTP Program activities at the CTF site. Neither of these sites are considered significant under National Register criteria and all of the previous surveys of the area surrounding the TAN facility (which includes CTF) indicate a low probability for encountering additional cultural resources (Idaho State University 1986). Consultation with INEL's cultural resources

contractor, EG&G, confirmed that no further archaeological surveys would be required for SNTP Program activities at the CTF site. Because of these findings, no adverse impacts are expected to occur to archaeological resources if the CTF alternative is chosen for SNTP activities.

Recommended Mitigation

Although the known archaeological resources located within the CTF APE are not considered significant and the probability for additional sites is low, the presence of sites does indicate some potential for cultural resources to be discovered during the course of project activities. In the event that archaeological, paleontological, or Native American resources are discovered, ground disturbing activities would immediately cease and a qualified archaeologist would be notified; all subsequent actions would comply with 36 CFR 800.11 and the Native American Graves Protection and Repatriation Act (NAGPRA).

QUEST Alternative

Archaeological site EGG-92-2-1 is an extensive lithic and ceramic scatter that is unique to the INEL because of its size, complexity, and long history of occupation. Because of the amount, richness, and diversity of its cultural materials, it has the potential to contribute significantly to the current understanding of North American and Idaho prehistory and may therefore be potentially eligible to the National Register under criterion D. Archaeologists familiar with the area indicate that it is unique, as well, because of chinked basalt structures found along the lava ridge that do not appear elsewhere on the INEL. Although the density in the distribution of cultural material at this site fluctuates from area to area, the entire APE for this program (including the access road) contains cultural material, thereby making avoidance virtually impossible. Because of these findings, extensive direct and indirect impacts would occur to cultural resources if the QUEST alternative is chosen for SNTP activities.

Archaeological and paleontological sites are finite, nonrenewable resources, whose salient characteristics are easily diminished by physical disturbances. Because of this, avoidance and preservation in place is the preferred treatment. In consideration of the above described cultural resources complex at the QUEST site, the Air Force has recognized the significance of the identified resources and has removed the QUEST site from consideration as an alternative for SNTP program activities.

If, however, the QUEST alternative is reconsidered for future program activities, the following mitigation measures are recommended:

If avoidance is not possible or practicable, implementation of the following mitigation measures, in consultation with the Idaho SHPO and the Advisory Council on Historic Preservation, can reduce adverse effects at the QUEST site to a non-adverse level; consultation would continue until such time that all requirements under Section 106 have been satisfied.

Prior to any ground disturbing activities:

- Evaluation of archaeological site EGG-92-2-1 to determine its eligibility to the National Register
- The access road from ANL-W to the QUEST site requires improvement. Previous surveys along this road have recorded numerous sites and indicate that some may be eligible to the National Register; these sites would also require evaluation
- Development and implementation of a research design and data recovery plan based on the Secretary of the Interior's Standards and Guidelines: Archaeology and Historic Preservation
- Implementation of the research design would be under the direction of a qualified archaeologist, as described in 36 CFR 61, Appendix A(b) and would include but not be limited to:
 - Detailed mapping/photography
 - Archaeological/paleontological subsurface testing or non-destructive testing as appropriate
 - Curation of recovered artifacts in accordance with 36 CFR 79
- Archaeological monitoring during all ground disturbing activities

- Other mitigation measures developed during the consultation process.

I. Attachments

Four Figures

J. Respository

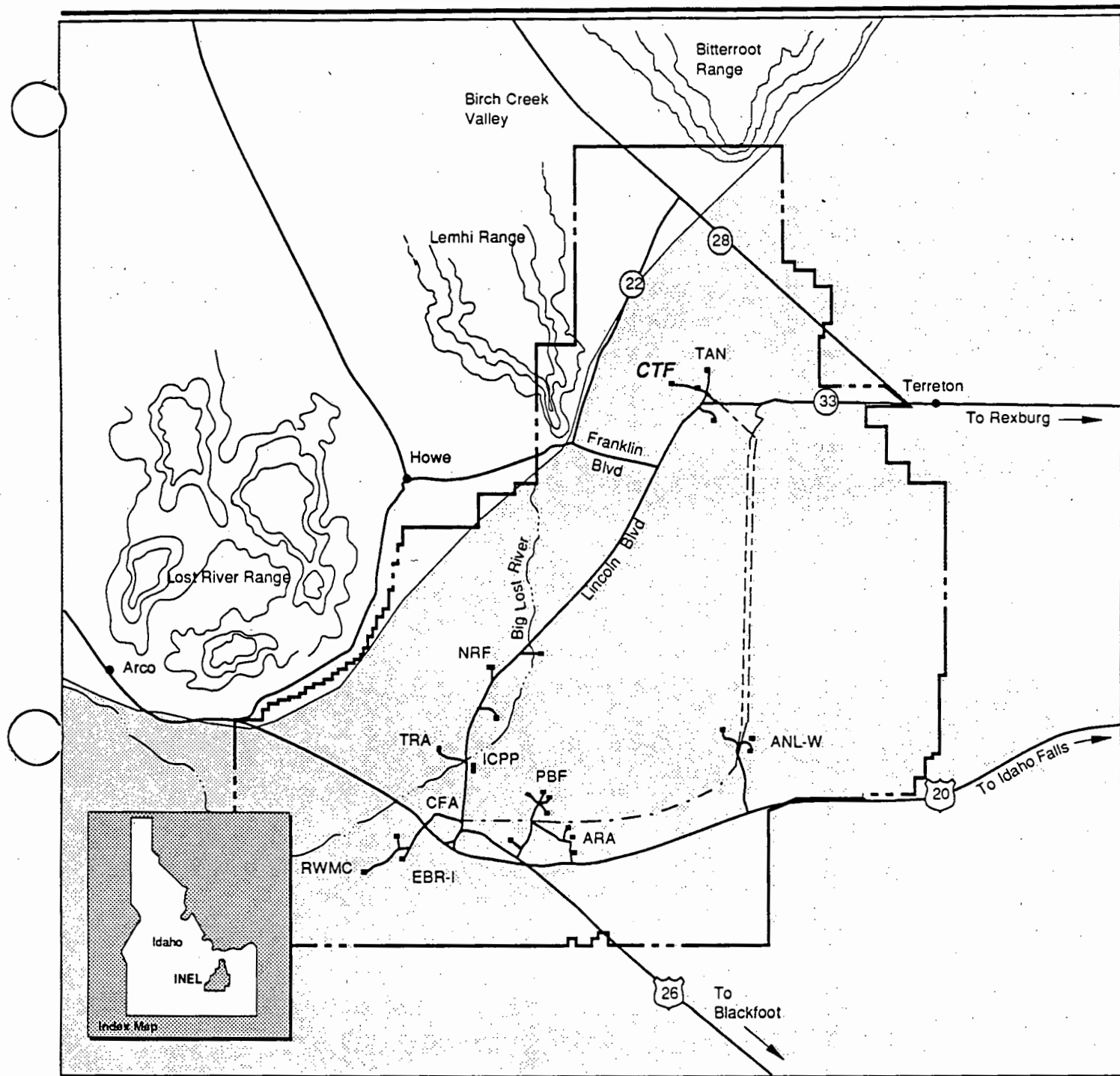
The Earth Technology Corporation
1461 East Cooley Drive
Suite 100
Colton, California 92324

K. Certification of Results

I certify that I conducted the investigation reported here, that my observations and methods are fully documented, and that this report is complete and accurate to the best of my knowledge.

Paige M. Peyton
Paige M. Peyton, Field Director

June 2, 1992
Date

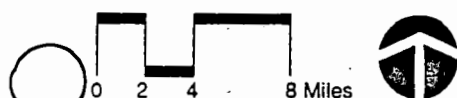


EXPLANATION

- Transmission Line
- - - - - Dirt Road
- Snake River Plain

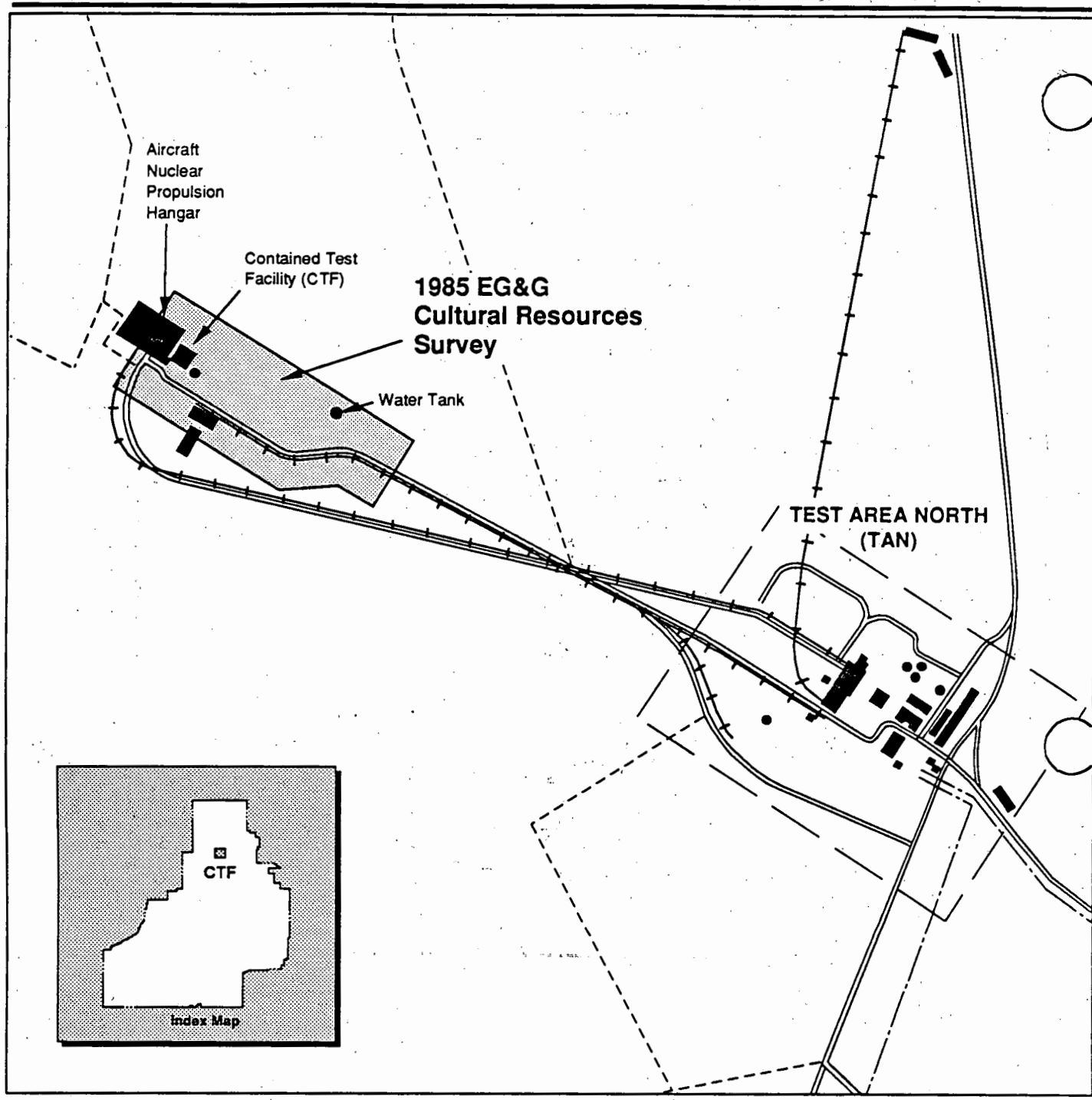
Idaho National
Engineering
Laboratory

CTF Site



PHL/038-2

Figure 1



EXPLANATION

- Dirt Roads
- Transmission Lines
- 1985 EG&G Survey



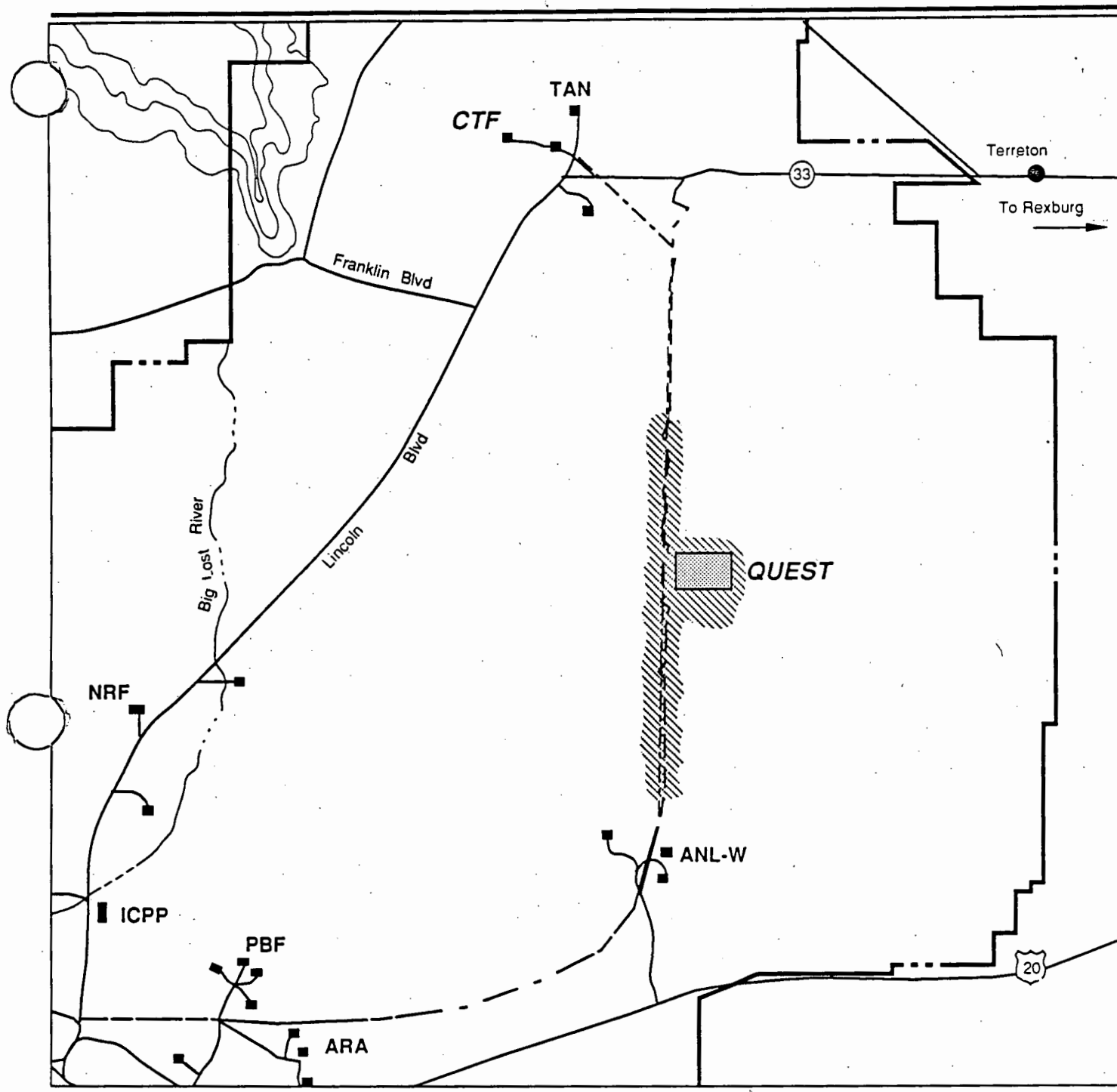
PHL017-3

G-12

Idaho National
Engineering
Laboratory

CTF Site
Cultural Resources
Survey

Figure 2



EXPLANATION

-  Cultural Resources Sensitivity Area
-  Transmission Line
-  Dirt Road
-  INEL Boundary

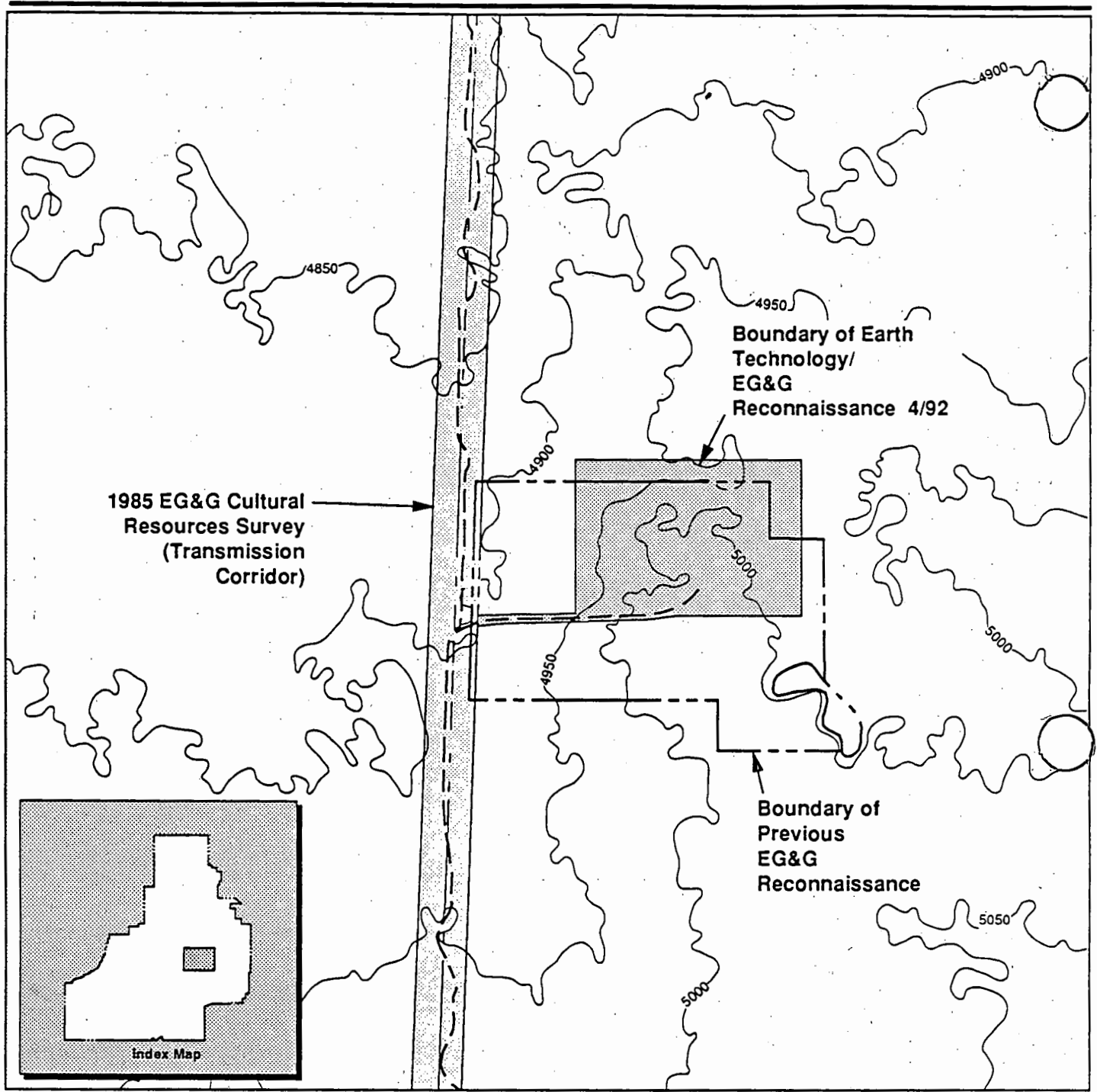


PHL/036-1

Idaho National
Engineering
Laboratory

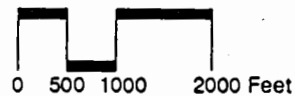
QUEST Site
Cultural Resources
Sensitivity

Figure 3



EXPLANATION

- · — · — Transmission Line
- - - - - Dirt Road
- Boundary of Earth Technology/EG&G Reconnaissance 4/92
- Boundary of Previous EG&G Reconnaissance



Idaho National
Engineering
Laboratory

QUEST Site
Cultural Resources

Figure 4



IDAHO STATE HISTORICAL SOCIETY

CECIL D. ANDRUS, Governor

RECEIVED
CLAYTON E. MARLER

NOV 18 1991

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Oral History
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Boise, Idaho 83702
208-334-3863

Publications
450 N. 4th St.
Boise, Idaho 83702
208-334-3428

November 15, 1991

Clayton Marler
E G & G Idaho, Inc.
P.O. Box 1625
Idaho Falls, Idaho 83415

Dear Clayton:

I am sorry it has taken so long to write and thank you, EG&G and the Department of Energy for the tour of the D & D facilities last August. Tom Thiel (EG&G), Andy Mikkola (DOE), and Roger Twitchell (DOE) were especially helpful in explaining the project.

As you know, we believe the various reactors and associated buildings, such as those at the ARA I, II, III, the Borax Reactor, MTR, ETR and the Hot Shop, are eligible for the National Register of Historic Places. We realize these facilities are not fifty years old, but they are of exceptional scientific and engineering significance, and all have played major roles in the development of nuclear science since World War II. Hence, the removal of these structures is an adverse effect under section 106 of the National Historic Preservation Act (NHPA) and DOE must consult with the Advisory Council.

We do recognize these are not normal facilities that can be preserved for the public like the EBR-1 reactor and the nuclear aircraft engines. Consequently these facilities need to be documented following the standards of the Historic American Engineering Record. This is a great opportunity (and requirement of the National Historic Preservation Act) to create a history, not only of these reactors, but of the whole INEL site.

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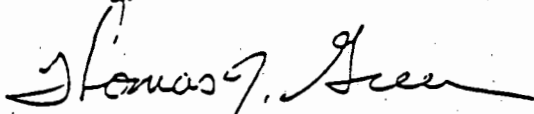


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Clayton Marler
November 15, 1991
Page 2

In order to comply with section 106 of the NHPA, DOE needs to consult with Advisory Council's Western Field Office in Denver (Claudia Nissley - (303) 231-5320. A programmatic agreement needs to be written that will outline the various mitigative requirements. We will be happy to help prepare such an agreement.

Sincerely,

A handwritten signature in dark ink, appearing to read "Thomas J. Green". The signature is fluid and cursive, with the first name "Thomas" being more prominent and the last name "Green" following in a similar style.

Thomas J. Green
Deputy State Historic
Preservation Officer

TJG:dac

FROM: DOE-EEM NV

TO:

512 536 3498

JUN 26, 1992 10:57AM P.02

BOB MILLER
Director

STATE OF NEVADA

PETER G. MORRIS
*Director*RONALD M. JAMES
State Historic Preservation Officer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF HISTORIC PRESERVATION AND ARCHEOLOGY
128 W. Nye Lane, Room 208
Capitol Complex
Carson City, Nevada 89710
(702) 687-5138

June 19, 1992

Dr. Donald R. Elle
Environmental Protection Division
Nevada Operations Office
Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518

Dear Dr. Elle:

The Division of Historic Preservation and Archeology received the following DOE cultural resources report for review:

A Class III Cultural Resources Reconnaissance of the Proposed Saddle Mountain Project, Area 14, Nevada Test Site, Nye County, Nevada (NTS-923414).

Intensive archaeological survey failed to reveal any historic properties within the area of potential effect. As no historic properties were found, the DOE has completed its Section 106 consultation with this office for the proposed Saddle Mountain Project, unless archaeological materials are encountered during construction.

Sincerely,

A handwritten signature in cursive script, reading "Eugene M. Hattori".

Eugene M. Hattori
Archaeologist

ACTION file
INFO _____
MGR. _____
MA _____
SMESH _____
AMO _____
AMTS _____



IDAHO STATE HISTORICAL SOCIETY

CECIL D. ANDRUS, Governor

June 8, 1992

Director

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Publications

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208-334-3428

Ms. Paige Payton
Senior Project Environmental Specialist
Cultural Resources Management
The Earth Technology Corporation
275 West Hospitality Lane
Suite 220
San Bernardino, California 92408

RE: Space Nuclear Technology Program

Thank you for notifying our office that the Department of the Air Force has identified the QUEST Site and the LOFT Site on the Idaho National Engineering Laboratory as potential locations for the Space Nuclear Thermal Propulsion (SNTF) Program ground test station. After reviewing our records, we have the following comments:

1.) QUEST Site (T4N, R32E, Sec.11,12,13,14): Consultation with EG&G Cultural Resource Management (CRM) staff indicates that a large archaeological site has been identified within the SNTF project boundaries at the QUEST Site. Because construction of the facility would adversely effect the site, the Advisory Council on Historic Preservation will have to be consulted.

2.) LOFT Site (T6N, R31E, Sec.11,14): Construction of the ground test station at the LOFT Site would require modifications to the existing LOFT facilities. Since the facility is eligible for the National Register, archival research and documentation of the existing structures need to be completed prior to alteration. As well, an archaeological assessment of the project area should be conducted.

Ms. Paige Payton
June 8, 1992
page 2

Once we receive more detailed information on the proposed construction, we will consult with EG&G CRM staff and your office on specific recommendations. If you have any questions, feel free to contact either myself or Suzi Neitzel at 208-334-3847.

Sincerely,

Susan P. Neitzel

Thomas J. Green *for*
Deputy State Historic
Preservation Officer

TJG/spn

cc: Brenda Ringe, EG&G Idaho
Clayton Marler, EG&G Idaho

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APPENDIX H

NATURE OF RADIATION AND ITS BIOLOGICAL EFFECTS

APPENDIX H

NATURE OF RADIATION AND ITS BIOLOGICAL EFFECTS

This appendix provides a discussion of the nature and effects of ionizing radiation. A glossary of terms can be found in Table H-1.

1.0 NATURE OF RADIATION

The basic unit of matter is the atom, consisting of a heavy central nucleus surrounded by electrons moving about the nucleus in orbits or a "cloud". The nucleus, containing nearly all the mass of the atom, is comprised of protons and neutrons, particles with virtually the same mass. Neutrons are electrically neutral; protons have a positive electrical charge, designated as +1. The electrons have less than 1/1,800 of the mass of protons and neutrons and a unit negative charge, i.e., -1. Complete atoms are electrically neutral with the same number of protons and electrons, referred to as the atomic number. (Atoms with unequal numbers of protons and electrons are called ions.) The chemical nature of the atom, and its identity as a chemical element, is determined by the atomic number. Hydrogen, for example, has one proton in its nucleus (and one orbiting electron); helium has two, lithium has three, etc.

Different nuclear species, or nuclides, are presented by their chemical element designation (their atomic number) and the sum of protons and neutrons in their nuclei. For example, the nuclide carbon-12 has six protons (the atomic number for carbon) and six neutrons; carbon-14 also has six protons but eight neutrons. Sometimes nuclides are denoted by other conventions utilizing the chemical symbols, e.g., C-12 and ^{12}C for carbon-12. Nuclides with the same number of protons but different numbers of neutrons are called isotopes of the chemical element. For example, hydrogen (one proton) has three isotopes with zero, one, or two neutrons, referred to as hydrogen-1, hydrogen-2, or hydrogen-3, respectively.

In some nuclides, the combination of protons and neutrons form a stable nucleus with tendency to change its configuration. Of the more than 2,000 nuclides identified to date, only about 280 are stable. In unstable nuclides, called radionuclides, the nucleus undergoes a spontaneous process known as radioactive decay to attain a more stable configuration. This radioactive decay is accomplished by the emission of particles and/or energy from the nucleus. The most usual particle emissions are referred to as alpha or beta radiation. Alpha particles consist of two protons and two neutrons; beta particles are electrons (originating in the nucleus, not from the orbiting cloud outside the nucleus). Energy emitted from the nucleus is in the form of gamma radiation, "packets" of electromagnetic energy, called photons, traveling at the velocity of light.

Table H-1. Glossary of Terms

Nuclide:	An atomic nucleus with a specific number each of protons and neutrons.
Radionuclide:	Any nuclide which is unstable and has the potential to decay by radioactive emission.
Alpha Radiation: (Alpha particle)	Radioactive emission that consists of two protons and two neutrons (a helium nucleus).
Beta Radiation: (Beta particle)	Radioactive emission that consists of one electron.
Gamma Radiation: (Gamma ray)	Radioactive emission that consists of a packet of energy emitted as electromagnetic radiation (a photon).
Curie:	Unit of radioactivity equal to 3.7×10^{10} radioactive decay events per second.
Specific Activity:	The number of radioactive decays occurring in a unit mass (usually 1 gram) of radioactive material.
Half-life:	The time required for one-half of the radionuclides present in a radioactive sample to decay. This rate is a unique constant for each radioisotope.
Absorbed dose:	The amount of energy deposited in a unit mass (generally 1 kilogram) of material being irradiated.
Rad:	Unit of absorbed dose equivalent to the deposition of 0.01 joule of energy per kilogram of absorbing material.
Rem:	Unit of exposure to biological material calculated by multiplying the dose (in rads) by a quality factor which accounts for the biological effectiveness of the type of radiation producing the exposure.
External Exposure:	Exposure received to the whole body due to a radiation source which is physically located outside the exposed organism.
Internal Exposure:	Exposure received to either the whole body or a individual organ(s) from radioactive material which has been chemically incorporated into the body (through inhalation, absorption, etc.)
Maximum Exposed Individual (MEI):	The location of maximum radiological impact (highest dose) in unrestricted access areas. This location represents the site of the maximum exposure a person could receive if present throughout the exposure duration.
Somatic Effects:	Radiation-induced effects observed in the exposed individual, most commonly cancer.
Genetic Effects:	Radiation-induced effects observed in the progeny of exposed individuals or populations, including effects not apparent for multiple generations.

An important characteristic which has been observed for this radioactive decay process is that it is probabilistic; that is, the precise time at which any specific unstable atom will decay cannot be determined. Also, in a sample of a number of the unstable atoms, it cannot be determined which of them will decay at any point in time. It has been observed that the ratio of the number of nuclei which decay in a unit of time to the number of undecayed nuclei remaining in the sample is a constant for each nuclide. This ratio is called the decay constant. The number of decays, or disintegrations, in a unit time is called the activity of the sample. Traditionally, activity is measured in curies, a term derived from the activity of 1 gram of radium and numerically equal to 37 billion disintegrations per second. Dividing the activity by the mass of the sample gives the specific activity for the sample. Since decay may be characterized by a constant, the time required for one-half of the nuclei in a sample to decay is also constant for each nuclide. This time is referred to as radioactive half-life for the nuclide.

2.0 EXPOSURE MECHANISMS

As the emitted particles and gamma radiation move away from the emitting nucleus, they collide with the atoms in the surrounding material. These collisions dissipate the kinetic energy of the particles and the electromagnetic energy of the gamma rays and, in the process, the atoms in the surrounding material may be damaged; that is, their structure may be changed such that their chemical nature and function is modified. The most common damaging effect is the removal of one or more of the surrounding electrons from an atom. As a result, the atom is no longer electrically neutral and is said to be ionized. The damage is related to the amount of energy deposited by the incident radiation. The deposited energy is referred to as the absorbed dose and is measured in rads; one rad is equal to the deposition of 0.01 joule of energy per kilogram (2.2 pounds) of the absorbing material.

If the absorbing material is living matter, the damage to the atoms may produce chemical changes which result in the death of living cells or other biologically harmful effects. Different types of radiation vary in their effectiveness in producing biological harm. Quality factors have been identified for various types of radiation which, when multiplied by the absorbed dose, account for these differences. This yields a measure of biological harm, referred to as dose equivalent, which is the same for all types of radiation and is quantified in terms of rem. This allows quantitative comparisons on the effects among the different types of radiation and the determination of overall effective exposures when different types of radiation are involved.

Radioactive materials have the potential to produce an exposure either through external means, primarily from gamma photons and some high

energy beta particles (both of which are penetrating and have long ranges), and internally due to deposition of alpha and beta particle emitting materials.

External doses are received equally throughout the body, and hence are referred to as whole-body doses. Such doses occur due to the penetrating power of the radiation involved. Externally, three mechanisms are of concern:

- **Cloudshine** is exposure due to gamma exposure from airborne radioactive materials. Although such airborne materials may be remote from the person being exposed, the long range of the gammas allows some radiation to reach the person.
- **Groundshine** is exposure due to gammas emitted from radioactive materials which have deposited on the ground.
- **Immersion** is similar to cloudshine, but is exposure to both gamma photons and high energy beta particles emitted by airborne radioactive materials. The exposed individual is actually within the radioactive cloud (rather than being located remotely, as is the case with cloudshine), which allows the addition of exposure due to the high energy beta particles.

Internal exposure is due to direct exposure of tissue to radioactive materials which have entered the body. Such materials can then chemically interact the way nonradioactive isotopes of the same elements would, and can be distributed to various parts of the body. Indeed, some materials exhibit a tendency to collect in a particular organ or system, thus concentrating the dosage received. This occurs with iodine, which preferentially accumulates in the thyroid, and various metals, phosphorus, and calcium, which accumulate in the bones. The whole body and individual organ doses received (since dose is based upon energy absorbed per unit mass of material different body parts can receive different exposures) can, therefore, vary widely. There are three exposure mechanisms of significance in analyzing internal exposure:

- **Inhalation:** Breathing of airborne radioactive materials (which would occur during immersion) allows deposition of particulates (in the lungs which may later be absorbed), and direct passage into the body of radioactive gases.
- **Ingestion:** Eating and drinking of contaminated plants, animals, and water can allow radioactive materials to enter the body through the digestive system. Once in the body, these materials behave as do their nonradioactive forms, and will interact chemically in the body.

- **Absorption:** Some radioactive materials can be absorbed directly through the skin, where they will again interact as other chemical materials in the body.

The environmental pathways for the contamination and exposure of individuals and the public in general are mutually dependent and interconnected by an array of subpathways. For instance, radionuclides deposited on ground surfaces can be sources of external dose through groundshine and sources of internal dose through the ingestion pathway. Internal dose through ingestion can occur directly as a result of ingestion of contaminated vegetation (through uptake of radionuclides from the ground) or indirectly as a result of ingestion of animal products from animals that have grazed on contaminated vegetation. Also, bodies of water contaminated by liquid releases can be sources of internal exposure, either directly through ingestion of contaminated water or indirectly through ingestion of contaminated aquatic foods or food crops contaminated by uptake of radionuclides in water used for irrigation (i.e., through the food chain).

External exposures are received only during the period of actual exposure to radioactive releases. Internal exposures, however, are more persistent, since radioactive materials that enter the body may take considerable time to be released. During this time radioactive decays continue to contribute to the total dosage received. As a result, the total dose from a radioactive release that a person receives has two components; the first is the external dose which is received during a short span of at most a few hours following release (although groundshine and resuspension inhalation may persist much longer), and the second is the long-term dose incurred as a result of internal deposition of radioactive materials. Such a dose may be distributed over a period of years.

The various organs of the body have different susceptibilities to harm from radiation, and different organs may receive different doses from internal exposure to radioactive material that they accumulate. However, by applying organ-specific weighting factors to individual organ doses, it is possible to determine a whole-body result as an indicator of health risk due to internal exposure. Combining this information with the total whole body dose received from external exposure yields the total dose due to a radioactive release. The millirem (mrem) ($1,000 \text{ mrem} = 1 \text{ rem}$) is used as the unit of measure for total dose. Total dose is calculated for all exposure due to a radioactive release received by the individual in the subsequent 50 years (a 50-year committed dose).

The consequences of radiological releases are presented in two ways in the MELCOR Accident Consequence Code System (MACCS) analysis. First is the maximum-case potential exposure. This is referred to as the "maximally exposed individual" (MEI), and can be defined as the maximum potential

whole-body dose that any individual can receive due to a release or series of releases. The summation of all release impacts in a year is used to determine the MEI, compliance with the National Emissions Standards for Hazardous Air Pollutants (NESHAP) standard of 10 mrem, and compliance with the program goal of 2 mrem. Second, the total population dose is calculated by MACCS, which is the summation of the total dose to all exposed people, and is expressed as "person-mrems". This quantity can be used to determine the potential number of cancer fatalities and genetic defects in the exposed population which can be expected in subsequent years as a result of the total population exposure. This is accomplished by multiplying the population dose by the risk factors contained in the report issued by the Fifth Committee on the Biological Effects of Ionizing Radiation (BEIR V), which specifies a risk of 7.9×10^{-7} cancer fatalities per person-mrem, and 2.6×10^{-7} genetic defects per person-mrem.

3.0 HEALTH EFFECTS

If the whole body is exposed to a very high dose of radiation, death may occur immediately or within a matter of weeks. The dose that is lethal to about 50 percent of exposed individuals within 60 days after exposure is about 500,000 mrem (Abrahamson et al., 1989). If a limited area of the body is exposed briefly to a very high dose, death may not occur but there may be other early (sometimes called "acute") effects. For example, doses to the gonads (i.e., testes or ovaries) might cause sterility. Such effects are considered to be acute or short-term effects, and are due to massive damage to bodily systems. Short-term health effects are usually not observed below an acute dose of about 25,000 mrem, although changes in blood cells have been detected at doses as low as 5,000 mrem (National Council on Radiation Protection [NCRP], 1971). Estimated doses to the general population from normal operations of reactors and support facilities are in the range of fractions of mrem per year of operation and fall well below the level that would produce acute effects. Thus, acute effects due to normal reactor operations are not considered credible health threats.

Doses of radiation that are well below the thresholds needed to produce observable acute effects may have consequences later in life. Such doses can produce latent, or delayed, health effects. Delayed health effects can be broken down into two types: latent somatic effects and latent genetic effects.

Latent somatic effects are those directly observable in the exposed individual, the most important of which is the possible development of cancer years after exposure. Although the basic processes by which radiation induces cancer may not be fully understood, studies of the survivors of the atomic bombings in Japan, patients exposed to radiation, uranium workers, and workers in the radium-luminizing industry (1930s) have established that the incidence of cancer is greater in groups who were

exposed to high doses of radiation in earlier years than in groups who were not exposed.

Latent genetic effects are those that are observed in the offspring of exposed individuals, including effects that may not become apparent for several generations. Latent genetic effects are due primarily to mutations in the genetic material of exposed persons.

The data that established a link between cancer, genetic effects, and radiation were collected for persons who received high doses; no equivalent direct statistical link has been established between cancer and low doses of radiation. However, a conservative assumption is that the probability of a delayed effect is proportional to dose (linear dose-risk relationship); therefore, a reduction in dose by one half would result in half the number of persons developing the effect, a reduction by ten would result in a tenth the number of persons developing the effect, and so on. Also, a linear dose-risk relationship would enhance the meaningfulness of the population dose as a measure of radiation effects on a population, since the predicted effects would be based upon the population exposure regardless of how the exposure was distributed among the individuals.

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