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L-20768-1

Fissile Material Disposition Program

PEIS Data Call Input Report:
Immobilization of Surplus Fissile Material with Electrometallurgical Treatment of Spent Fuels

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LAWRENCE LIVERMORE NATIONAL LABORATORY
University of California • Livermore, California • 94550

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Preface

Significant quantities of weapons—usable fissile materials (primarily plutonium and highly enriched uranium [HEU]) have become surplus to National defense needs both in the United States and Russia. The excess stocks of plutonium and HEU pose significant dangers to national and international security. The dangers exist not only in the potential proliferation of nuclear weapons but also in the potential for environmental safety, and health consequences if excess fissile materials are not properly managed. Under the direction of the President of the United States, the Department of Energy (DOE) is examining options for placing weapons-usable nuclear materials in a form or condition that is substantially and inherently more difficult to use in weapons. The potential environmental impacts of facilities designed to implement this objective for plutonium will be described in the Fissile Material Disposition (MD) Programs *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (PEIS).

This MD PEIS data report is based on the use of existing facilities and support systems including radioactive waste treatment facilities, industrial waste treatment facilities, electrical utilities, domestic water facilities, and the infrastructure to support facility construction and operation (e.g., safeguards and security, transportation, fire protection, medical, purchasing, training, financial support).

This alternative is one of several immobilization options being considered by the Fissile Material Disposition Program. Other options such as direct geologic disposition and mixed oxide fuel technology are also being considered.

This document was co-authored or reviewed by the following:

James J. Laidler	ANL-E
Charles C. McPheeters	ANL-E
Terry R. Johnson	ANL-E
Martin K. Clemens	ANL-E
Yoon I. Chang	ANL-E
Dean R. Pedersen	ANL-E
George S. Stanford	ANL-E
Thomas J. Moran	ANL-E
Ira Charak	ANL-E
Charles E. Dickerman	ANL-E
Richard Simms	ANL-E
Edward K. Fujita	ANL-E
Robert N. Hill	ANL-E
Michael J. Lineberry	ANL-W
Harold F. McFarlane	ANL-W
Kenneth M. Goff	ANL-W
Tehmau Kan	LLNL
Leonard Gray*	LLNL
Albert DiSabatino	LLNL/SAIC

* Author to whom all questions should be directed.

* Author to whom all questions should be directed.

1.0 Electrometallurgical Treatment Facility—Missions, Assumptions, and Design Basis

1.1 Facility Missions

Immobilization of plutonium alloys and transuranic (TRU)-rich residues is carried out in conjunction with the electrometallurgical treatment of DOE spent nuclear fuels in existing facilities at Argonne National Laboratory-West (ANL-W). The ANL-W facilities are being equipped for high-throughput electrometallurgical treatment of DOE spent fuel stored at the Idaho National Engineering Laboratory (INEL). For the purpose of the this report, the activities are described as taking place within the ANL-W facilities.

The primary purpose of the electrometallurgical treatment process is to convert spent fuel into disposable waste forms. The product streams include (1) pure uranium; (2) miscellaneous metal wastes containing the noble metal fission products, cladding, and reactor assembly hardware; and (3) zeolites containing the alkali metal, alkaline earth, and rare earth fission products. The zeolites are converted to a glass-bonded zeolite (GBZ) waste form, and the miscellaneous metals are formed into ingots of a corrosion-resistant metal waste form; both forms will be required to be suitable for disposal in a geologic repository. The TRU elements in the spent fuel could be combined with the GBZ waste form or the metal waste form for disposal; however, the GBZ waste form is described as the reference case in this document.

The equipment to treat a variety of irradiated fuels, such as EBR-II and Fermi-Reactor fuels, and some TRU-rich wastes, such as plutonium oxides and chloride processing salts (molten salt extraction and electroresinning spent salts) and produce the three product streams has been developed at least through the pilot plant stage. Some of the equipment is currently in operation in the ANL-W hot cells. The processes to convert the product streams into waste forms have been developed, and the pilot-scale waste conversion equipment is being designed as part of an ongoing R&D program supported by DOE/Nuclear Energy (NE) and Environmental Management (EM). It is assumed that all necessary equipment will be installed as a part of the DOE/NE and EM programs and can also be used for the plutonium immobilization program.

As described in this report, the processes to immobilize weapons-grade plutonium and minor actinides are integrated with spent fuel treatment using the same hot cells and some of the same equipment. The weapons-grade plutonium is combined with the GBZ waste form which also contains the TRU elements from the fuel. Any additional equipment needed to immobilize the larger amounts of weapons-grade materials is similar to that used to handle the waste streams from spent fuel treatment. Fissile

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those environmental impacts and resource requirements that result from plutonium disposition and that are in addition to the impacts and resources associated with spent fuel treatment are discussed.

1.2.2 Facility Capacity and Capability

The nominal feed of plutonium and minor actinides is 50 tonnes, (55 tons) of heavy metal. The feed consists of a combination of metal, TRU-rich oxides, and chloride salts. Although any mix of these materials can be handled, the feed materials are assumed for this report to be 25% metal, and 75% oxides and chlorides. In conjunction with the spent fuel operations, the ANL-W facilities can immobilize at least 5 tonnes (11,000 lb) per year of surplus fissile materials; thus, the 50 tonnes (55 tons) can be handled in less than 10 years. The process has a daily feed rate of about 25 kg (55 lb) of plutonium and minor actinides. The fissile materials are shipped in and products placed in interim storage at rates adequate to maintain the processing rate. Two- to three-month inventories of feed materials will be stored on-site.

During the same 10-year period, the ANL-W facilities will treat all of the spent EBR-II fuels and will demonstrate treatment of a variety of other DOE-owned fuels. In this report, the preferred form for plutonium is GBZ, which will also contain the TRU elements and some of the high-level waste streams from fuel treatment. Fission product cesium from the Hanford capsules will be stabilized in GBZ form to reduce the risk of diversion of the weapons-grade plutonium.

Operations to immobilize surplus fissile materials are performed 18 hours per day for 200 days per year. Repair, maintenance, and special material accountability are performed on the off-shift and remaining days of each year.

The plutonium loading in the GBZ waste forms will be identified during the R&D program, but for the purposes of this conceptual design, it will be 5 wt% plutonium and minor actinides. Neutron absorbers are added to the waste forms as necessary to decrease the probability of criticality in a repository.

The accessibility of the fissile material waste forms is decreased by the addition of ^{137}Cs obtained from the spent fuels and the cesium capsules stored at Hanford. The process to separate fission product cesium from the spent fuel and incorporate it into the GBZ form is part of the fuel treatment operations. The same process equipment is also used to convert the $^{137}CsCl$ in the Hanford capsules to GBZ. Fission products from the spent fuel provide only a fraction of the protective radiation field.

The ANL-W hot cells are in the final stages of being prepared for the electrometallurgical treatment of spent fuel. Immobilization operations will not require additional construction or new equipment, and permitting will be required in addition to the existing Idaho EPA and DOE permits. Process equipment for immobilization is based on a modification of existing equipment, or is similar to that being developed for spent fuel electrometallurgical treatment, e.g., hot press for ceramic forms. The existing ANL-W support facilities, e.g., offices, analytical laboratories, waste treatment, and security, are adequate for the proposed immobilization operations.

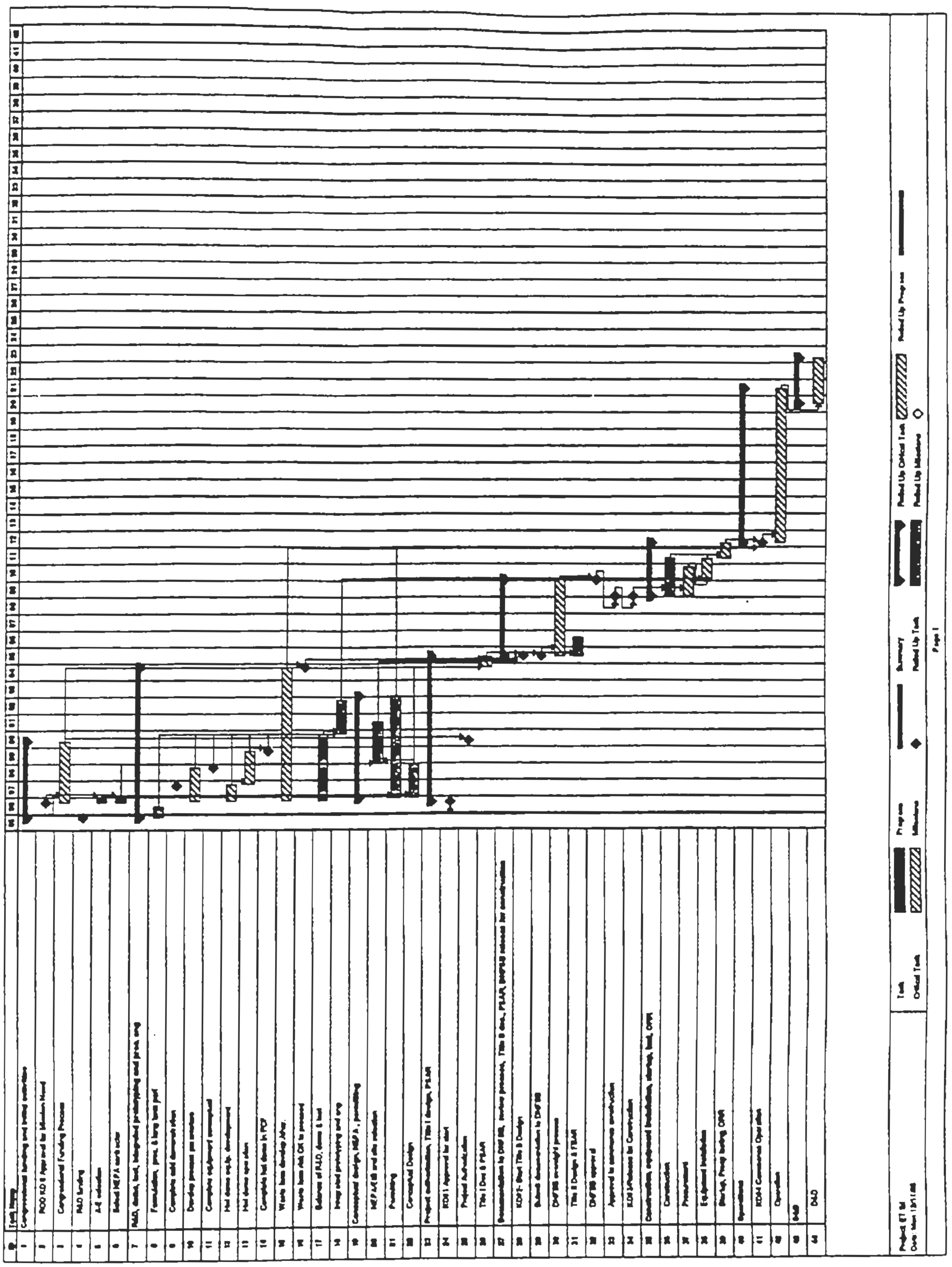


Figure 1-1. Schedule for immobilization of surplus fissile materials and DOE spent fuel treatment in ANL.

National Environmental Protection Act (NEPA) activities are included. For this alternative using existing DOE facilities, it is assumed that a site-specific Environmental Impact Study will be required following the programmatic EIS.

Permitting activities are indicated. Preparation of a Safety Analysis Report is included. Title I & II (preliminary and detailed) design durations are indicated. Construction and procurement durations are included. Cold startup, preoperational testing, and an Operational Readiness Review (ORR) of the facility is included, followed by hot startup and operations.

The time to process the reference 50 tonnes (50 tons) of plutonium will vary with plutonium loading and actual operating scenarios. For planning purposes, the estimated duration of the plutonium immobilization campaign is 10 years. Process improvements, plutonium immobilization experience, and increased plutonium loading could shorten this schedule.

Decontamination and decommissioning duratios are included. The decommissioning method assumed for the schedule is complete dismantlement and restoration of the site for unrestricted use. Other methods (layaway, protective storage, etc.) or combinations of methods, depending on time, cost benefit studies, or radiation exposure, might be selected with an impact to the time required.

1.2.4 Compliance

The existing ANL-W hot cell facilities meet DOE standards to handle large quantitie of fissile materials, and have licenses from the Idaho EPA to operate processes similar t spent fuel treatment. It is assumed that only minor modifications of the DOE and EPA permits will be needed to carry out the proposed immobilization operations.

1.2.4.1 Rules, Regulations, Codes, and Guidelines. The weapons-grade plutonium immobilization program envisions the utilization of existing facilities at the ANL-W site. Pending the outcome of further analyses of the process, only relatively minor modifications to those facilities, at most, are expected. Table 1-1 lists potentially applicable regulations covered in the Code of Federal Regulations (CFR) and in DOE orders. Also included are consensus codes and standards that might be relevant to facility- and equipment-related design. The listing should not be considered all inclusive, since many of the listed requirements themselves reference additional standards, rules, etc., and not all requirements can be anticipated at such an early stage of the process. Also, some judgment has been exercised to omit those requirements tha are of only minor importance relative to the design and construction of structures and hardware, and the safe operation of the program. On the other hand, the inclusion of a specific requirement or standard should not be construed as necessary for the accomplishment of the program since the existing facilities, as already noted, may be adequate without significant modifications, thereby obviating the need for design standards. The standards would only apply, as applicable and necessary, to important backfits and major modifications, if any. Finally, many of the cited DOE orders may be

Table 1-1. (continued)

Citation	Subject
U.S. Department of Energy Orders (continued)	
DOE Order 5480.19	Conduct of Operations Requirements for DOE Facilities
DOE Order 5480.20	Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Nuclear Facilities
DOE Order 5480.21	Unreviewed Safety Questions
DOE Order 5480.22	Technical Safety Requirements
DOE Order 5480.23	Nuclear Safety Analysis Reports
DOE Order 5480.24	Nuclear Criticality Safety
DOE Order 5480.28	Natural Phenomena Hazards Mitigation
DOE Order 5482.1B	Environment, Safety and Health Appraisal Program
DOE Order 5483.1A	Occupational Safety and Health Program for DOE Contractor Employees at Government Owned Contractor Operated Facil
DOE Order 5500.1B	Emergency Management System
DOE Order 5632.1C	Protection and Control of Safeguards and Security Interests
DOE Order 5633.3B	Control and Accountability of Nuclear Materials
DOE Order 5820.2A	Radioactive Waste Management
DOE Order 6430.1A	General Design Criteria
U.S. Department of Energy Standards	
DOE-STD-1020-94	Natural Phenomena Hazards Design and Evaluation Criteri Department of Energy Facilities
DOE-STD-1021-93	Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components
DOE-STD-1027-92	Hazard Categorization and Accident Analysis Techniques f Compliance with DOE Order 5480.23, Nuclear Safety Analy Reports
DOE-STD-1073-93	Guide for Operational Configuration Management Progran
American Concrete Institute	
ACI 318	Building Code Requirements for Reinforced Concrete
ACI 349	Code Requirements for Nuclear Safety Related Concrete Structures
American Institute of Steel Construction	
AISC M016	Manual of Steel Construction Allowable Stress Design
AISC N690	Specification for the Design, Fabrication, and Erection of S Safety-Related Structures for Nuclear Facilities

Table 1-1. (continued)

Citation	Subject
American National Standards Institute	
ANSI N13.1	Guide for Sampling Air Borne Radioactive Materials in Nuclear Facilities
American Society of Mechanical Engineers	
ASME AG-1	Code on Nuclear Air and Gas Treatment
Boiler and Pressure Vessel Code	Pressure Vessel Design
ASME N509	Nuclear Power Plant Air-Cleaning Units and Components
ASME N510	Testing of Nuclear Air Treatment Systems
Institute of Electrical and Electronics Engineers	
IEEE N42.17	Performance Specifications for Health Physics Instrumentation
IEEE N42.18	Specification and Performance of On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents
IEEE N317	Performance Criteria for Instrumentation Used for In-plant Plutonium Monitoring
IEEE N323	Radiation Protection Instrumentation Test and Calibration
IEEE 308	Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
IEEE 323	Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
IEEE 338	Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems
IEEE 344	Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
IEEE 384	Standard Criteria for Independence of Class 1E Equipment and Circuits
National Fire Protection Association	
NFPA 70	National Electrical Code
NFPA 70B	Recommended Practice for Electrical Equipment Maintenance
NFPA 70E	Standard for Electrical Safety Requirements for Employee Workplaces
NFPA 72	National Fire Alarm Code
NFPA 101	Life Safety Code
NFPA 110	Emergency and Standby Power Systems
NFPA 780	Lightning Protection Code
NFPA 801	Recommended Fire Protection Practice for Facilities Handling Radioactive Materials

replaced by nuclear safety requirements expected to be published in the Federal Register under Title 10 of the Code of Federal Regulations.

1.2.4.2 Safeguards and Security. ANL-W has in place the safeguards and securi systems required by DOE orders to protect the tonne-quantities of weapons-usable plutonium currently stored on site, in accord with the Master Safeguards and Securi Agreement for the ANL-W site. The mass tracking near-real-time computerized material accountability system plays an important role in preventing diversion or th of fissile materials. The Zero Power Physics Reactor (ZPPR) facility used for storing tonne-quantities of weapons-usable plutonium is a fully approved Category I facilit The safeguards and security systems specified in the Nuclear Material Control and Accountability Plan addendum for FCF operation as a Category I facility have been reviewed by DOE. They fully meet DOE Order 5633.3B, *Control and Accountability* *Nuclear Materials* and other applicable requirements. These Category I provisions would be extended to Fuel Manufacturing Facility (FMF) and Hot fuel Examinatio Facility (HFEF) if required. Specific references applicable to the safeguards and sec systems provided in the design are discussed in detail in Section 2.3 of this report.

1.2.4.3 Environment, Safety, and Health (ES&H). The primary objective of th facility ES&H programs is to protect the environment and the health and safety of employees and public by minimizing the danger from hazards through design fea and through administrative controls. These programs encompass seven main area environmental protection, shipments, general safety, electrical safety, fire protecti industrial safety, and health and industrial hygiene. Complete descriptions of the programs can be found in the *ANL-W Environment, Safety and Health (ES&H) Man* which is maintained by the ANL-W Environment, Safety, and Waste Managemen (ESWM) organization. In addition, the *ANL-W Radiological Control Manual* imple the *DOE Radiological Control Manual* (DOE/EH-0256T). Finally, the basic criticalit safety requirements of DOE Order 5480.24, *Nuclear Criticality Safety*, are impleme both ANL sites by the *Nuclear Safety Procedures Manual*. At ANL-W, site-wide sp requirements are further identified in the *General Plan for Nuclear Criticality Safety* *ANL-W*. Each facility in which fissile materials are handled in quantities exceedi minimum threshold is required to prepare a criticality hazards control statement details the criticality safety issues unique to that facility. A description of overall safety policy follows.

The purposes of the ANL Health and Safety Policy are to ensure that activitie conducted at the Laboratory do not expose personnel, property, and the enviro undue hazards, and to promote a healthy and safe workplace for all employees. ANL operating contractor, The University of Chicago, has established a Board o Governors for Argonne National Laboratory. The Board has issued the followi statement regarding safety in the conduct of operations at the Laboratory:

It is the policy of the University of Chicago Board of Governors for Argonne National Laboratory that worker and public safety is given the highest priority in the conduct of Laboratory activities, including the safety of nuclear operations and the protection of the environment.

The Laboratory's Health and Safety Policy reflects the Board's and expands upon it as follows:

It is the policy of Argonne National Laboratory that its activities will be conducted in such a manner that worker and public safety is given the highest priority. The Laboratory will comply with all applicable federal and state health and safety laws, regulations, and orders to protect the health and safety of workers and the public, and to minimize accidental damage to property.

Safety at the Laboratory is a line responsibility extending from the Director to the Associate Laboratory Directors and Chief Operations Officer, to their respective division directors, department heads, facility managers, supervisors, and ultimately to all employees. Line managers must conduct facility operations and all other activities in compliance with applicable regulations, and in such a manner that the risk of hazards and potential threats to the environment, personnel, and property are reduced to the lowest practicable level.

Within the Laboratory, the Director has ultimate responsibility for ES&H. That responsibility is met through safety requirements on all operations by line organizations and is ensured by oversight and surveillance personnel independent of the line operations.

The Associate Laboratory Director for Engineering Research (ALD-ER) is directly responsible to the Laboratory Director for all aspects of ES&H associated with the weapons-grade plutonium immobilization program. Specialized support for such generic safety functions such as radiological protection, industrial hygiene, industrial safety, and fire protection is provided to the operating organizations by core technical groups at ANL-W reporting ultimately to the ALD-ER.

Division directors and department heads have primary responsibility for the safety of facility operations and all other activities in their organizations and for taking the necessary measures to ensure that all division or department buildings, facilities, and facility-related activities comply with established ES&H requirements.

Managers and supervisors are responsible for knowing and implementing applicable ES&H policies and directives, and for providing safety of personnel, facility operations, and all other activities that they supervise.

Employees are responsible for performing their work in a manner that will not endanger themselves or their coworkers and for complying with established ES&H rules and requirements.

The Assistant Laboratory Director for Environment, Safety, and Health, and Quality Assurance Oversight (AD-ESH/QA) is the principal safety officer of the Laboratory and is responsible for initiating action to establish and maintain overall Laboratory ES&H policies. Responsibilities also include determining the degree to which the policies are being effectively implemented at ANL-W. The AD-ESH/QA serves as the principal point of contact for the Laboratory to the University of Chicago Board of Governors' Safety and Environment Committee. He/She is supported by the ANL ESH/QA Oversight Directorate. This Directorate committee serves as a forum for identifying ES&H/QA issues on a Laboratory-wide basis. It advises the AD-ESH/QA on the development of strategies, policies, and practices in the area of ESH/QA; it ensures that input from programmatic and operational organizations is appropriately considered in this development process. It also ensures that strategies, policies, and practices are effectively communicated to the Laboratory population.

The ESH/QA Planning and Coordination Committee serves as a forum to advise Laboratory organizations on the development of practices and procedures in the areas of environment, safety, health, and quality assurance. This advisory group reviews requirements, issues, and concerns related to ESH/QA in order to communicate and facilitate programs that ensure supportive responses from the Laboratory community and the effective use of Laboratory resources.

Because operation of nuclear facilities is a significant part of the ANL research program, and because of the unique safety concerns associated with the use of nuclear materials, the Laboratory Director has established a separate oversight office for nuclear safety, as well as standing committees to review nuclear safety issues. The Office of Operational Safety (OOS), under the direction of the AD-ESH/QA, is responsible for planning, developing, and coordinating the Laboratory programs that ensure that operations associated with nuclear facilities and accelerators, and the handling, processing, and storage of special nuclear materials are conducted in accordance with DOE requirements. The OOS takes the necessary actions to provide for technical and administrative assistance to standing and *ad hoc* committees appointed by the Laboratory Director to review operations that have nuclear safety significance. The current standing committees are the Accelerator Safety Review Committee, the Reactor Safety Review Committee, and the Nuclear Facility Safety Committee.

The ANL Health and Safety Policy is implemented through a series of manuals, handbooks, and other documents, as appropriate to the operations of the Laboratory. In addition, each operating organization employs a management plan (or equivalent) to implement the Laboratory-wide high-level requirements outlined above. These plans typically include details of responsibilities and requirements for assuring that ES&H policies and goals are achieved in the operating environment that is unique to that organization.

1.2.4.4 Buffer Zones. Since the weapons-grade plutonium immobilization program will be executed in existing facilities located on the ANL-W site at INEL, there is no need to discuss buffer zones. Buffer zones are considered when a new site or a new facility on an existing site are under discussion. They relate to such issues as providing sufficient access around building exteriors to accommodate emergency vehicles, sufficient open space for security patrols, and the like (cf. DOE Order 6430.1A, section 0200). These matters are already well established by the existing infrastructure at the ANL-W site.

1.2.4.5 Decontamination and Decommissioning/Conversion. There are two elements related to decontamination/decommissioning (D&D) with respect to the immobilization program: (1) D&D as applied to the design of new facilities and (2) D&D as applied to the ultimate cleanup and disposal of equipment and facilities following completion of the program. These two elements are discussed below.

D&D Considerations in Design of New Facilities

When the Fuel Conditioning Facility (FCF) was renovated to accommodate the integral fast reactor program, D&D criteria were established for the design of new equipment. In general, the requirements of DOE Order 6430.1A, *General Design Criteria*, section 1300-11, were translated into specific FCF criteria. (These requirements expand somewhat on the general design requirements for D&D that are given in DOE Order 5820.2A, *Radioactive Waste Management*.) In particular, the design was required to incorporate features that would facilitate future decontamination. Issues that were specifically identified include provision of strippable coatings on floors, ceilings, and walls (or other suitable means) to ease cleanup, minimization of the length of ductwork that could contain radioactive materials, restriction to the extent practical of the confinement of particulate contamination to the source, and the like. For the purposes of the immobilization program, similar criteria will be established for any required new equipment and facilities.

D&D Following Program Completion

A plan to decontaminate and decommission the ANL-W facilities is being developed on the assumption that D&D activities will begin by about the year 2011 when the planned spent-fuel treatment activities will be completed. Immobilization work will only postpone D&D and should neither increase the difficulty of D&D nor add significantly to waste volume. The D&D program will implement the requirements of DOE Order 5820.2A, unless that order is superseded in the interim.

1.2.4.6 Nonsafety/Safety Class. Most of the ANL-W facilities that are likely to be used in this program were designed and built before the concept of safety-class equipment entered the nuclear lexicon. One exception to this statement is the FCF which, though built in the late 1950s and early 1960s, was recently upgraded to accommodate the integral fast reactor program. This upgrade program was accomplished using the latest DOE orders and standards (e.g., DOE Order 6430.1A, *General Design Criteria*) as well as current industry consensus standards (e.g., ASME/ANSI AG-1, *Code on Nuclear Air and Gas Treatment*). As a result, the FCF was substantially modified to include a safety-class emergency exhaust system and associated support systems. This equipment meets the safety-class criteria established in DOE Order 6430.1A.

Although safety analyses for the immobilization program have not yet been performed because the processes involved are similar to those discussed in the FCF FSAR, it is highly unlikely that additional safety-class equipment would be required for the program. Nevertheless, if such safety analyses demonstrate the need for safety-class equipment in the facilities to be used in the immobilization program, such equipment will be provided commensurate with the ability to backfit the facility and the programmatic requirements of schedule and cost.

1.2.4.7 Toxicological/Radiological Exposure. The ANL ES&H program described above in Sec. 1.2.4.3 includes considerations of toxicological and radiological exposure. In particular, the *ANL-W ES&H Manual* contains 25 sections that deal with various aspects of health and industrial hygiene, many of which relate directly to exposures to toxic and other hazardous materials. Among these are Industrial Hygiene Program, Toxic Materials, Carcinogens, and the like. These sections of the manual assign organizational and individual responsibilities for specific safety-related functions and provide implementing requirements.

Also as noted previously, the ANL-W radiological safety program is contained in the *ANL-W Radiological Control Manual*. This manual provides a one-to-one correspondence with the requirements contained in the *DOE Radiological Control Manual* (DOE/EH-0256T), giving the ANL-W implementing details.

1.2.4.8 Waste Management. Section 4 includes descriptions of the waste management issues that relate to the weapons-grade plutonium disposition program. The waste management program in place at ANL-W is designed to assure that all appropriate DOE and EPA requirements relevant to the safe handling of hazardous, radioactive, and mixed wastes are met.

The Idaho Operations Office of DOE has established criteria for the consistent and comprehensive management of waste flows at the INEL site, including the ANL-W operations. These criteria are the Reusable Property, Recyclable Materials, and Waste Acceptance Criteria. ANL-W has prepared the Waste Handling Manual as a tool to ensure compliance with these criteria. The Waste Handling Manual specifies the administrative responsibilities for the waste management program; it also provides guidance and procedures to be used to identify, characterize, treat, package, store, and dispose of any wastes generated by ANL-W activities.

2.0 Facility Description

2.1 General Description of the Facility

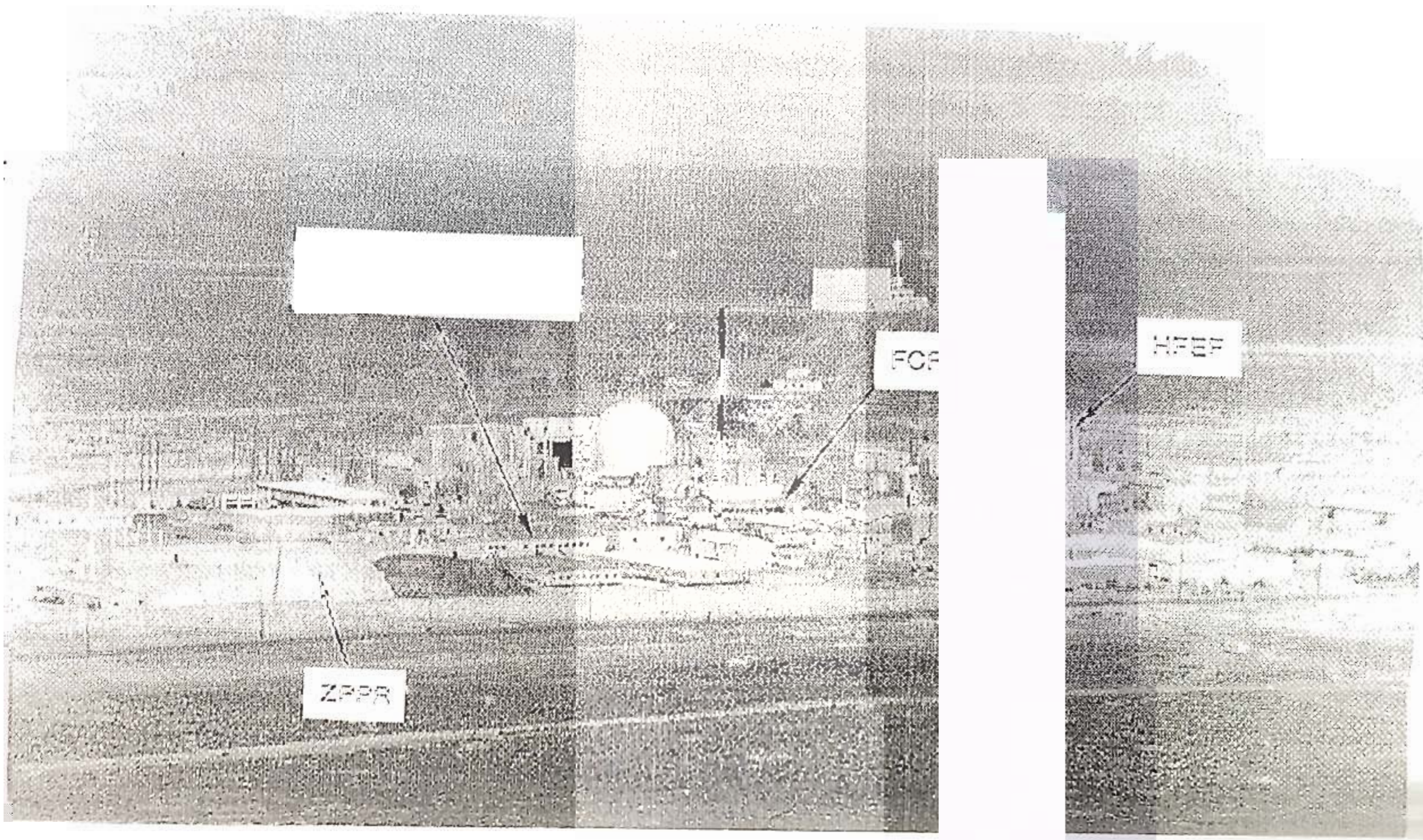
The existing facilities at the ANL-W site, located on the Idaho National Engineering Laboratory site can be used, in whole or in part, for this immobilization option. No major modifications of the ANL-W facilities would be needed to carry out the immobilization task at ANL-W. The facilities are currently performing similar functions. The location of INEL in the southeastern part of Idaho is described in Part 3. Figure 2-1 is an aerial view of the ANL-W site showing FCF, HFEF, ZPPR, and the laboratory and office building. Actual facilities are described in this report as a base for describing this immobilization option. If any new or modified facilities are required, they will include design, construction, and safety features equivalent to the properties described for existing facilities.

Any facilities actually selected or constructed for a DOE Electrometallurgical Treatment and immobilization mission will closely resemble the ANL-W facilities in size, function, equipment, emissions, and resource requirements. If there is a substantial electrometallurgical treatment program at another DOE site, it may be logical also to distribute the immobilization activities, for example, electrometallurgical treatment could be used to process the spent N-reactor fuel at the Hanford site.

2.1.1 Functional Description

The process described in this report immobilizes surplus fissile materials in the form of a glass-bonded zeolite that would be required to be suitable for geological disposal. This report is based on carrying out the immobilization in existing ANL-W facilities where DOE spent fuels are treated to produce disposable waste forms. The processes to immobilize surplus fissile materials and treat spent fuels are integrated and operate simultaneously. The immobilization plant is safeguarded to protect the fissile materials at all process stages, and it can be under international surveillance to prove denaturing of weapons-usable materials. The accessibility and attractiveness of the final product are decreased by providing a strong radiation field and degrading the plutonium isotopic composition.

Overall flows of materials through the immobilization system are shown in Fig. 2-2. Plutonium alloys and TRU-rich oxides and chlorides are shipped to the ANL-W facilities where they are stored temporarily. Cesium capsules shipped from Hanford are also stored temporarily in existing ANL-W facilities. As needed, these materials are transferred to the hot cell in FCF, where the immobilization and spent fuel processes are performed. The HFEF also contains a hot cell facility suitable for performing steps in the immobilization and spent fuel processes. The product GBZ waste forms are stored onsite temporarily before they are sent to a long-term storage facility or the repository.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FCF
HFEF

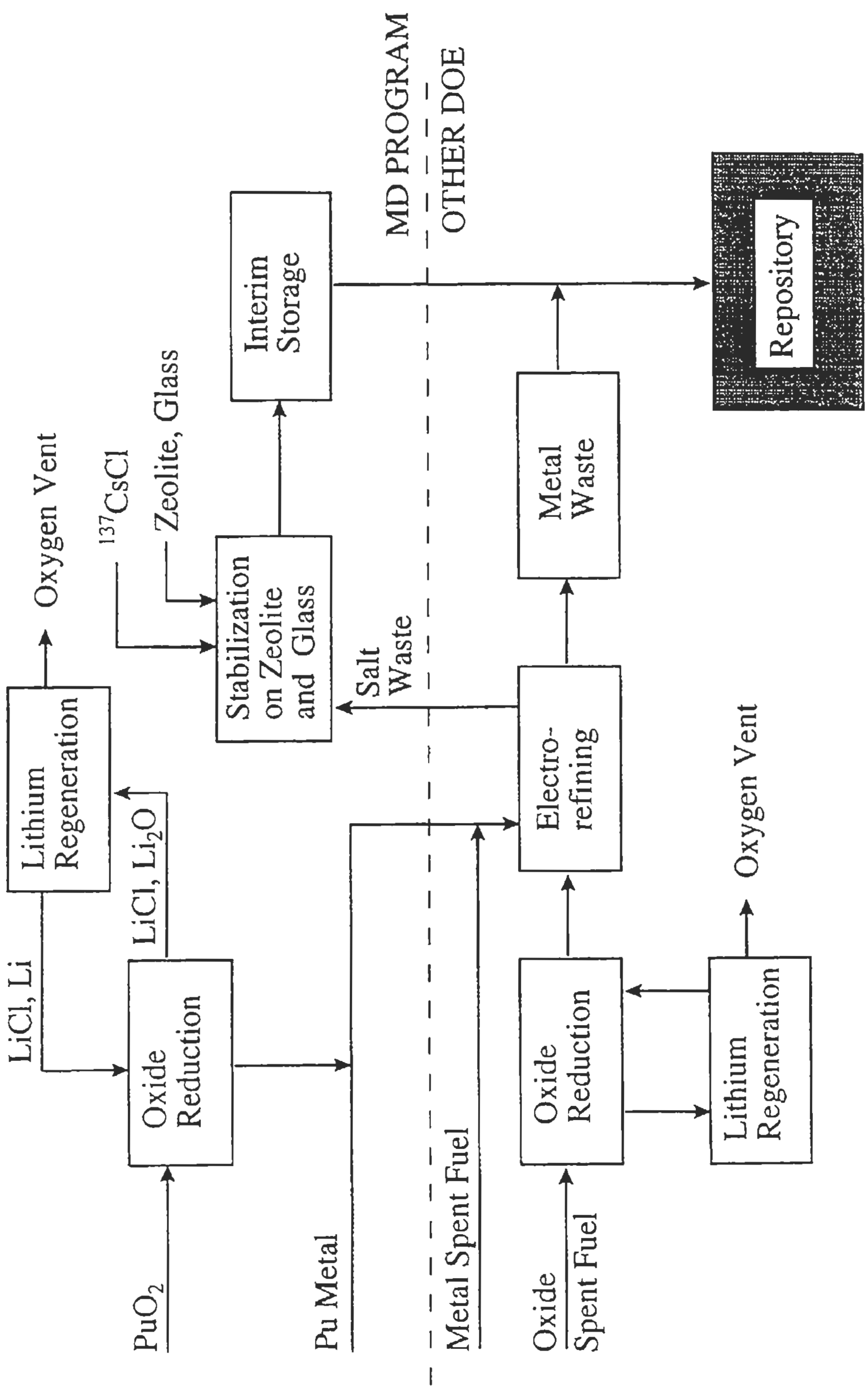

Figure 2-2. Integrated spent fuel treatment and fissile material disposition flowsheet.

The capacity of the Radioactive Scrap and Waste Facility will be expanded to provide storage space for all waste canisters produced (960 canisters).

A diagram of the material flows in the preferred fuel treatment and immobilization processes to immobilize plutonium and other TRU elements in GBZ is shown in Fig. 2-3. A second process to immobilize TRU elements in a metal waste form is shown in Fig. 2-4. Although the metal waste form option is not preferred, it is shown here because it is the basis for many of the estimates of accident impacts, resource utilization, etc., presented in this report. The metal option is used here as a bounding case, because it represents an upper bound on impacts of immobilizing surplus weapons-grade materials.

The process steps used to make the preferred GBZ waste forms containing fissile materials are shown in Fig. 2-3. In this case, the plutonium alloys and the TRU residues are fed to the spent fuel process; they leave the process in the spent chloride salt. Makeup salt is provided by waste salt from treatment of spent fuel, containing fission products and TRU elements. This salt is mixed with salt from the Hanford capsules and the spent chloride salt residues and passed through the zeolite bed. The actinides and the fission products are sorbed on the zeolite. Hot pressing produces the dense GBZ waste forms that contain about 5 wt% Pu and minor actinides. These forms are encapsulated in a sealed metal container.

In the second option process to make a metal immobilization form (Fig. 2-4), the TRU residues, oxides, and chlorides are treated in the spent fuel process producing a TRU-rich metallic mixture. The TRU-rich metals and other metallic process wastes, primarily fuel cladding and reactor assembly hardware, are combined with the TRU alloy in a furnace where they are melted and cast into ingots. This step is analogous to the step in the fuel treatment process to produce the TRU-free metal waste form as shown in Fig. 2-2. The pellets of GBZ containing cesium and other fission products are placed in the cavities case into the metal ingot, the cavities are sealed with metal plugs, and the ingots are encapsulated in a metal container. The metal immobilization case is included here only as a bounding case, as described above.

2.1.2 Plot Plan

The facilities that will be used in this immobilization project are as listed in Tables 2-1, 2-2(a), and 2-2(b). All of these facilities are in existence, and are currently authorized for operations similar to the immobilization operations. Figure 2-1 is a photograph of the facility and Fig. 2-5 is a layout that shows the location of most of the relevant buildings. The most important of the facilities are:

- The Fuel Conditioning Facility (FCF—Bldg. 765) and its supporting systems such as the Safety Equipment Building (SEB—Bldg. 709), where the safety-grade diesel generating and emergency exhaust systems are housed

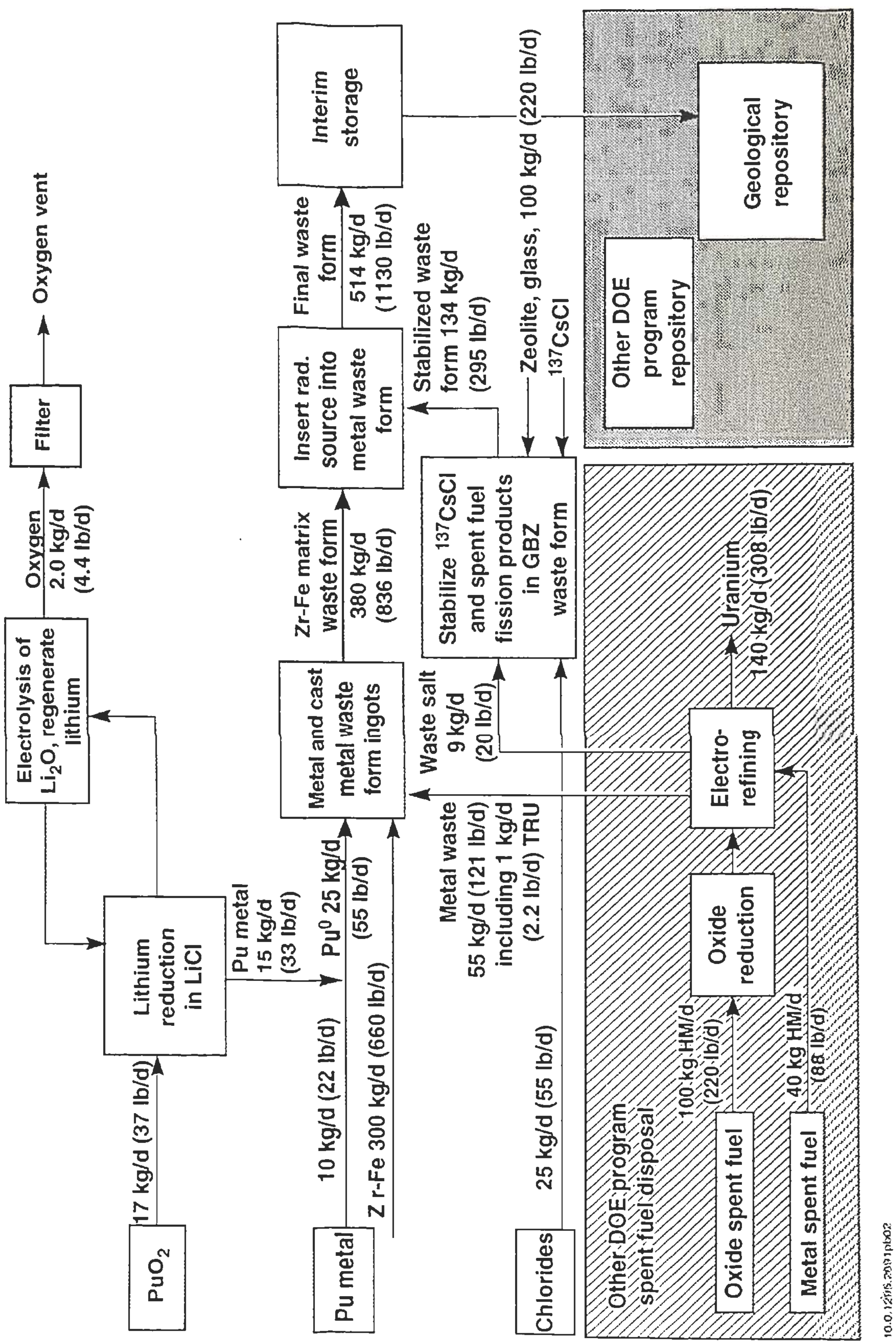

Figure 2-4. Electrometallurgical treatment, metal waste form.

Table 2-1. Data for major facilities.*

Building							
No.	Name	Footprint m^2 (sq. ft)	No. of levels	Note	Special materials	Construction type	Performance category
765	Fuel Conditioning Facility (FCF)	2100 (22,600)	4	a	Special Nuclear Material (SNM)	Reinforced concrete and steel frame	PC-3
709	Safety Equipment Bldg. (SEB)	230 (2,500)	1		No	Reinforced concrete	PC-3
785	Hot Fuel Examination Facility (HFEF)	1700 (18,400)	4	b	SNM	Reinforced concrete and steel frame	PC-3
776	Zero-Power Physics Reactor Bldg (ZPPR)	400 (4,300)	1		SNM	Reinforced concrete	PC-2
775	ZPPR Vault/Workroom/ Equipment Room	470 (5,000)	1		SNM	Reinforced concrete	PC-2
752	Laboratory & Office Bldg. (LOB) (includes cafeteria)	7800 (83,500)	1		Lab samples only	Reinforced concrete and masonry	PC-2
704	Fuel Manufacturing Facility (FMF)	440 (4,736)	1		SNM	Reinforced concrete	PC-2

Notes:

* All facilities now exist and are operational.

PC-3 Seismically qualified to standard PC3.

PC-2 Seismically qualified to standard PC2.

a FCF has four levels: a sub-basement (bagout room), a basement service floor, the main operating level, and a "roof" level (slated for decommissioning).

b HFEF has four levels: Service Area Basement, Operating Floor, Office/Data Collection level, and the High-Bay Area with a "hot repair" area and an area for Waste Isolation Pilot Plant (WIPP) characterization.

- The Hot Fuel Examination Facility (HFEF—Bldg. 785) also has hot cells for remote handling of materials
- The Zero Power Physics Reactor complex (ZPPR—Bldg 776); a detailed plot plan of the ZPPR complex is to be found in Fig. 2-6
- The Laboratory and Office Building (LOB—Bldg. 752); where the analytical facilities are located here
- The Fuel Manufacturing Facility (FMF—Bldg. 704), is a secure facility where glovebox facilities are located.

Table 2-2(a). Data for support facilities—Part 1*.

Building		
No.	Name	Footprint m² (ft²)
701	Security	540 (5,800)
702	Plant Services Equipment Storage	42 (450)
706	Construction Shop/Storage Building	560 (6,000
707	Fire Pump House	74 (800)
709	Safety Equipment	230 (2,500
710	Engineering Office	560 (6,000
742	Gasoline/Diesel Dispensary	9 (100)
749	1,500,000 L (400,000-gal.) Water Storage Tank	160 (1,700
752A	Diesel Generator bldg	19 (200)
753	Plant Services	2,200 (24,0
754	Well Pump House No. 1	130 (1,40
754A	760,000 L (200,000-gal.) Water Storage	121 (1,30
755	Fuel Oil Pump House	24 (260
755A	380,000 L (100,000-gal.) Fuel-Oil Storage Tank	307 (3,30
755B	190,000 L (50,000-gal.) Fuel-Oil Storage Tank	280 (3,000
756	Well Pump House No. 2	16 (170)
758	Electrical Substation	65 (700)
759	Fire House	251 (2,70
760	Sanitary & Industrial Waste Pump House	19 (200)
768	Power Plant	960 (10,30
768B	Water Chemistry Laboratory	65 (700
769	Dangerous Material Storage	102 (1,10
770C	Nuclear Calibration Laboratory	22 (240
771	Radioactive Scrap & Waste Facility	16,000 (1730)
773	300-kW Yard Substation	325 (3,50
774	ZPPR Support Wing	2,700 (29,3

* All facilities now exist and are operational.

Table 2-2(b). Data for support facilities—Part 2*.

Building		
No.	Name	Footprint sq m (sq ft)
777	ZPPR Equipment Building	46 (500)
778	Sanitary Sewage Lift Station	16 (180)
778A	Industrial Waste Lift Station	16 (180)
779	Sewage Lagoons	7,100 (76,000)
780	Laundry Sorting Building	60 (650)
781	Material Handling Warehouse	2,500 (26,400)
782	Machine Shop Facility	510 (5,500)
783	Rigging Test Facility	230 (2,400)
784	ZPPR Materials Control Building	460 (4,900)
786	HFEF 480-v. Substation	60 (640)
787	Fuel Assembly and Storage	560 (6,000)
790	Interim Contaminated Equipment Building	240 (2,600)
791	Instrument & Maintenance Facility (IMF)	790 (8,500)
792	ZPPR Mockup Building	280 (3,000)
793	Components Maintenance Shop	410 (4,400)
793C	Contaminated Storage Building	215 (2,300)
794	Contaminated Equipment Storage Facility	460 (4,900)
796	Metal Stock Control Building	440 (4,700)
797	Outside Radioactive Storage Area	1,400 (15,000)
798	Radioactive Liquid Waste Treatment Facility (RLWTF)	570 (6,100)
713	Offices	1,000 (10,800)
714	Offices	560 (6,000)
716	Offices	160 (1,700)
717	Offices	1,100 (11,400)
718	Offices	660 (7,100)

* All facilities now exist and are operational.

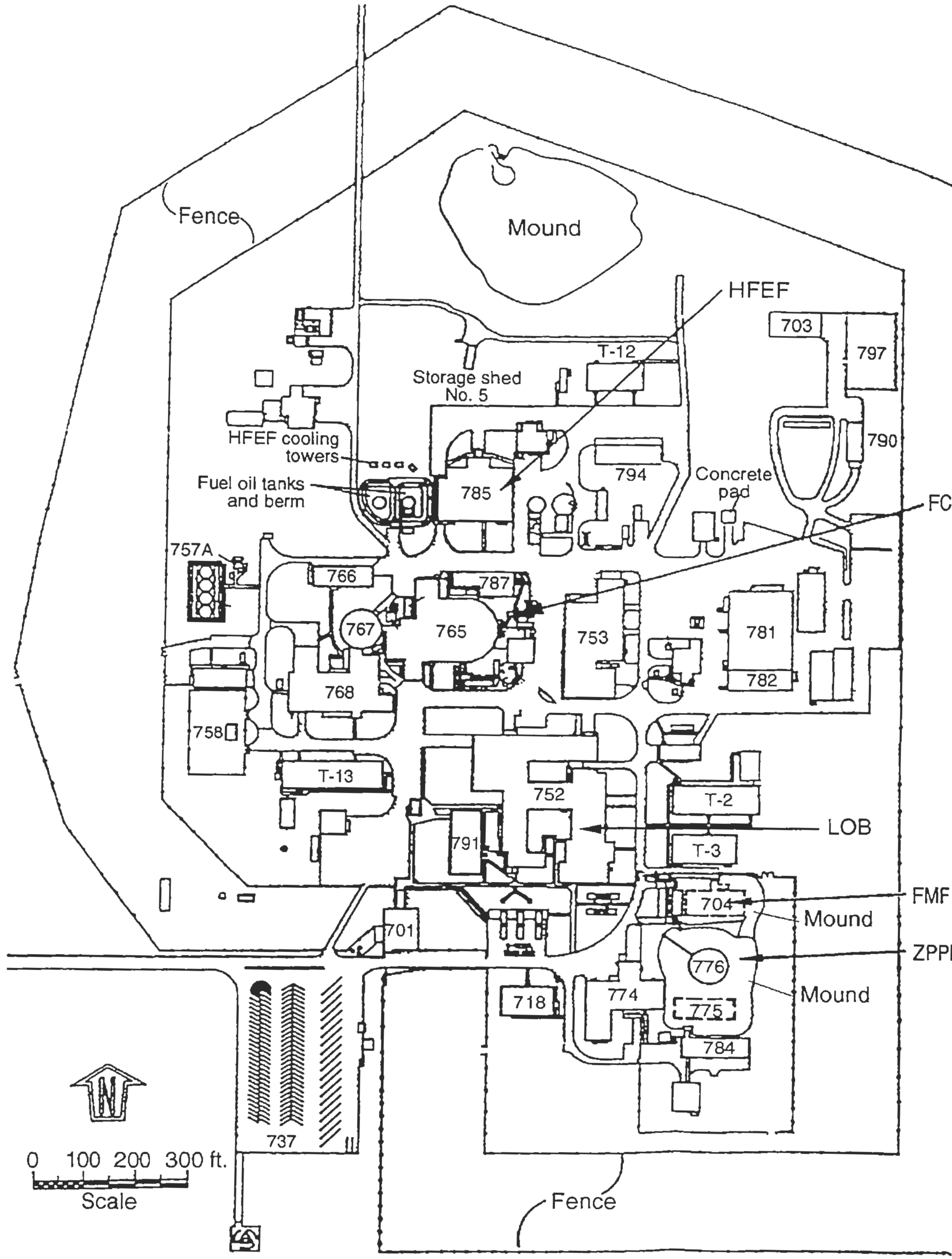

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Figure 2-5. Detailed layout of the ANL-W site.

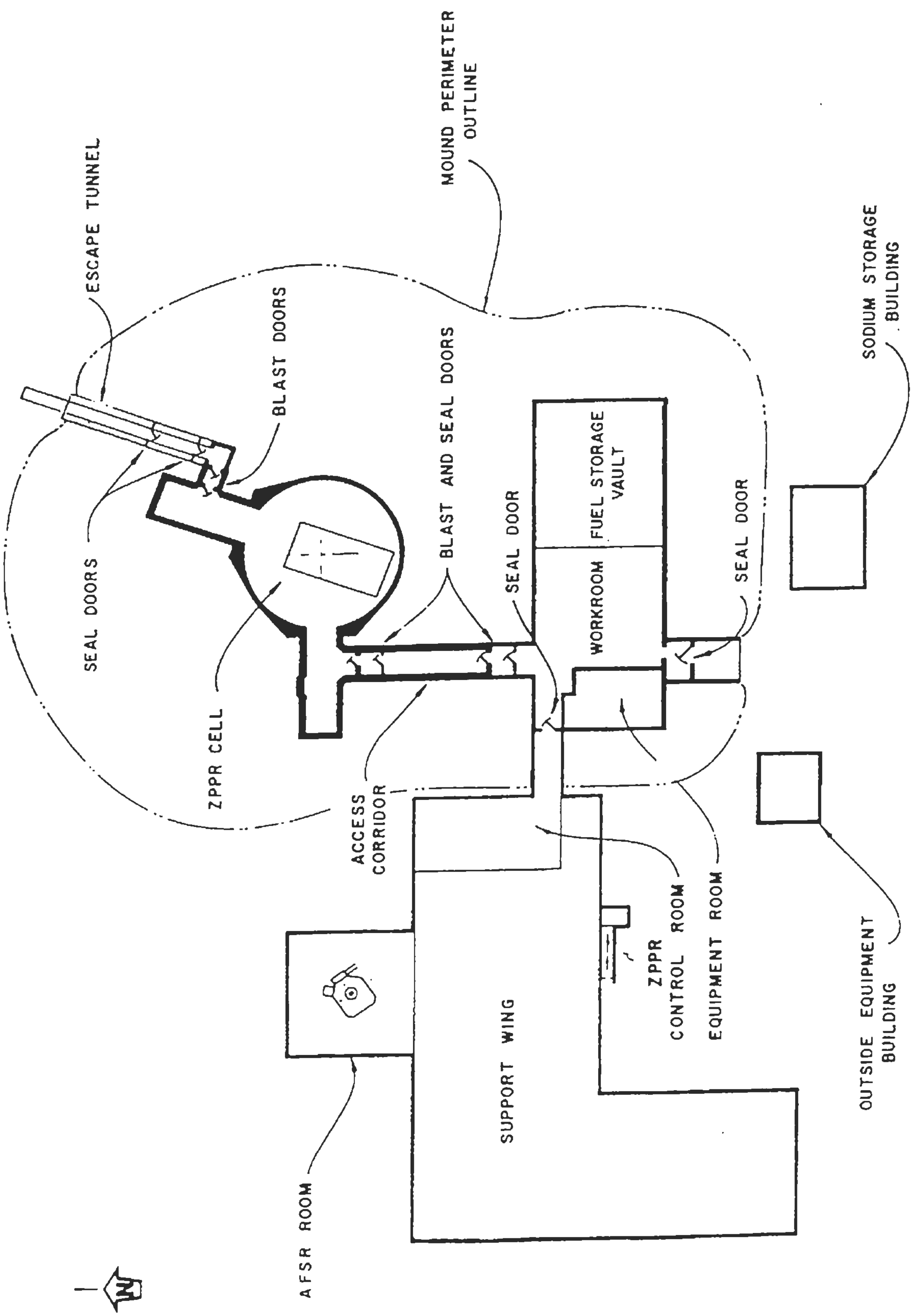


Figure 2-6. Plot plan of the ZPPR complex.

2.1.3 Building Descriptions

The major structures of relevance to special fuel treatment and immobilizati listed in Table 2-1 along with some pertinent parameters; and the relevant supp facilities are listed in Tables 2-2(a) and 2-2(b). No new construction is required.

FCF. The Fuel Conditioning Facility was designed and constructed from 19 1963 and was completely refurbished and upgraded to modern standards in 19 modern SAR, Operational Readiness Review (ORR), and Criticality Hazards Co Statement (CHCS) have been issued and approved in accordance with DOE Or 5480.23, 5480.22, and 5480.24.

Plan, elevation, and cross-section views of the FCF are shown in Figs. 2-7, 2- 2-9, respectively. The facility is composed of the FCF process building (i.e., the building, including the truck lock and the office annex), the SEB, the interconn tunnel, the safety equipment pit, and the exhaust gas stack. It occupies approxi 800 m^2 (~875 sq yd^2) at the ANL-W site. Most of the FCF structures have been designated as critical structures. Their critical functions consist of providing s the cells and the critical equipment, and providing protection from natural-phenomenon hazards. They also provide confinement barriers that contribute multiple lines of defense ("defense in depth") to satisfy as low as reasonably ac (ALARA) requirements. The FCF meets the structural requirements of DOE O 6430.1A, as well as other criteria.

The layout of the major equipment in FCF used in producing GBZ forms w elements and denatured with fission products is shown in Fig. 2-10. Figures 2- through 2-13 are photographs of electrorefiner, casting furnace, and cathode p systems that have been installed and demonstrated in FCF.

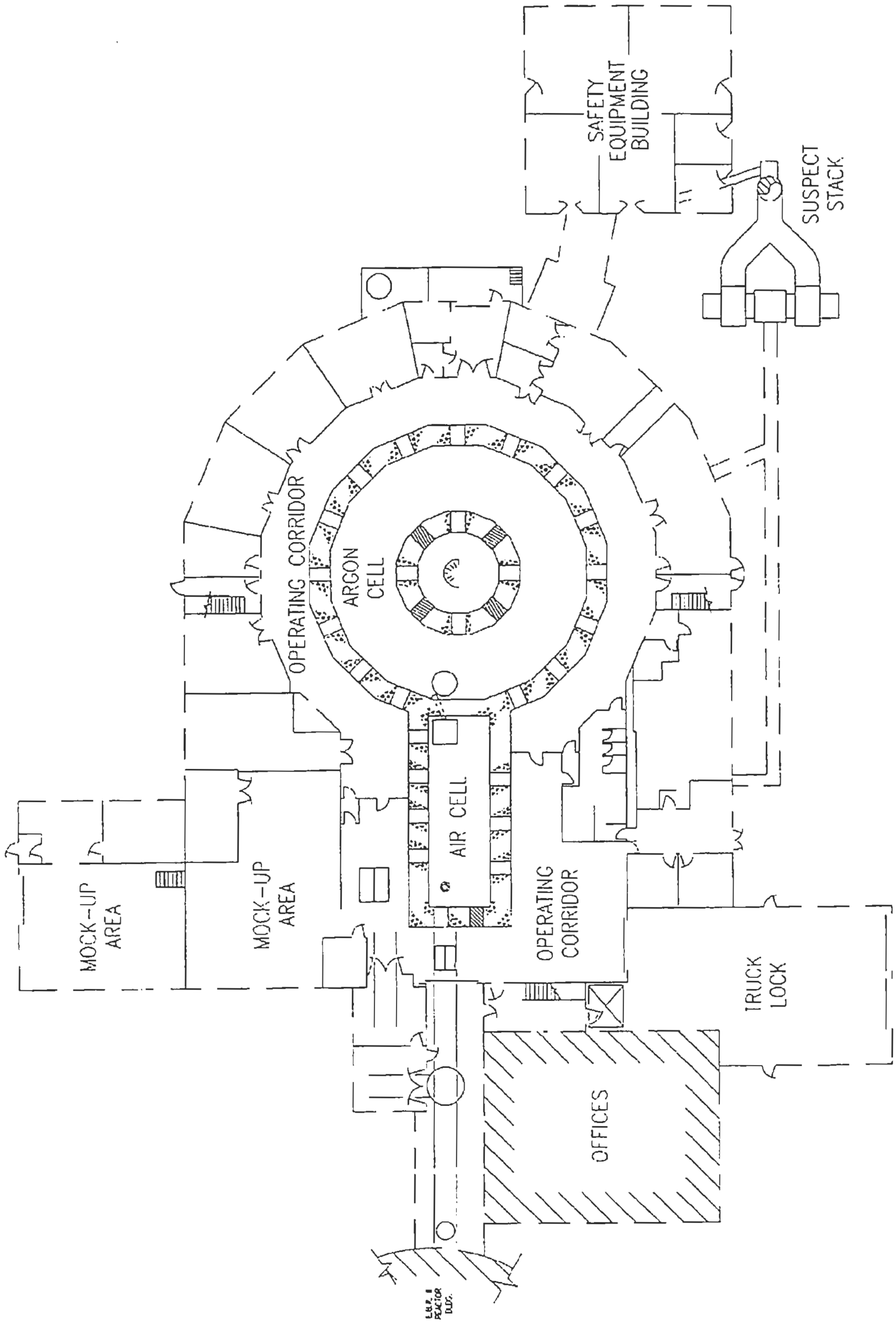


Figure 2-7. Layout of the FCF and the Safety Equipment Building.

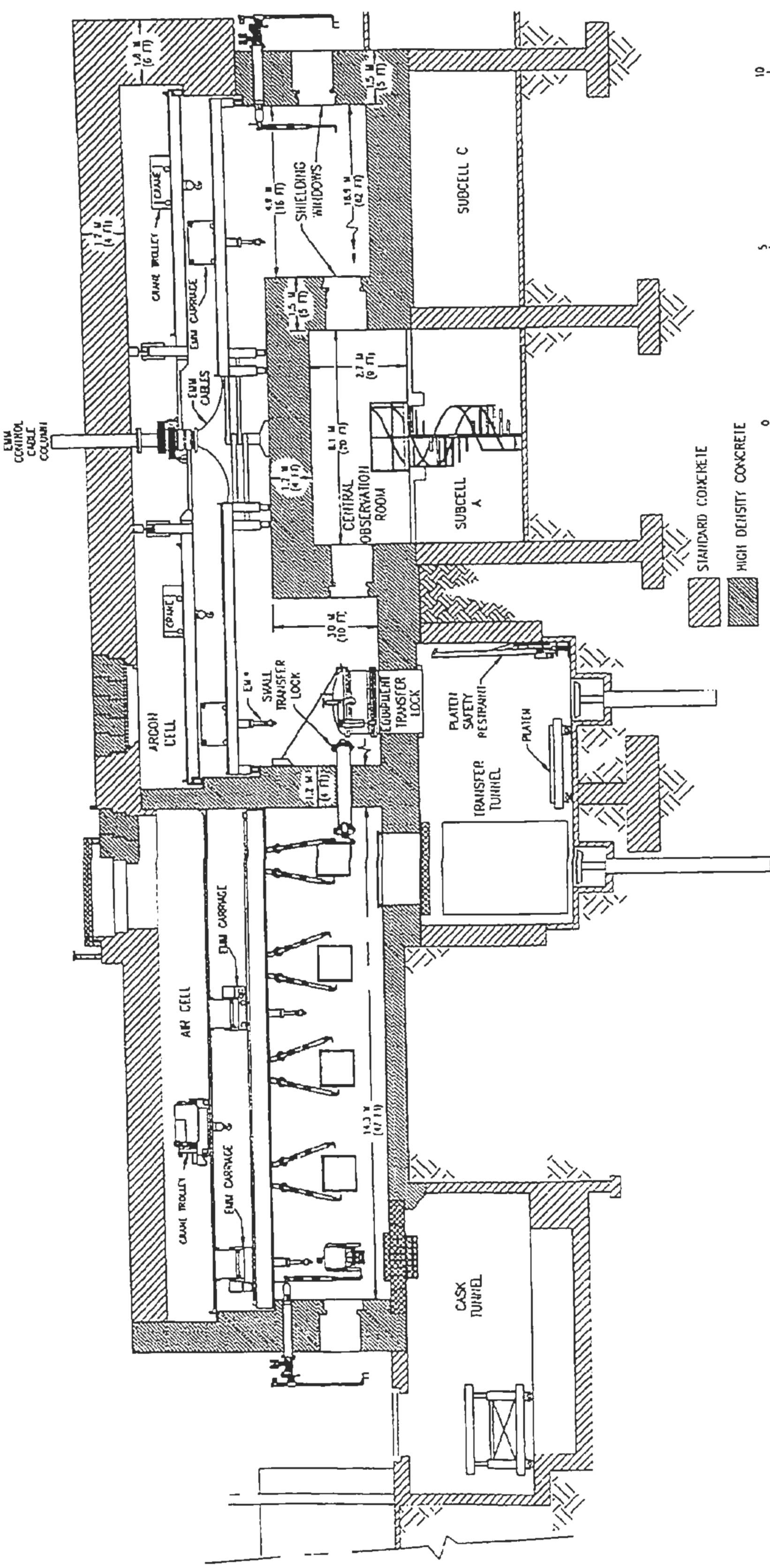


Figure 2-8. East-west elevation cross section of the FCF, showing the argon cells and basement area.

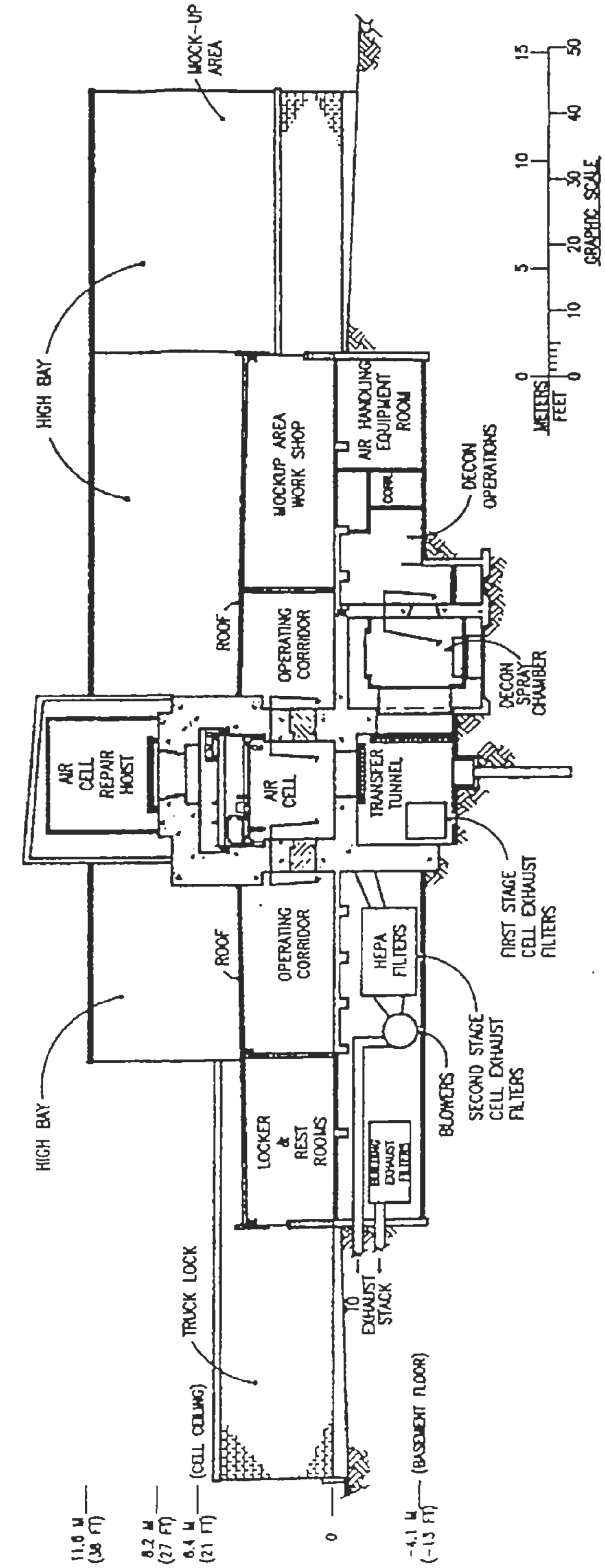


Figure 2-9. North-south elevation cross section of the FCF, at the location of the transfer tunnel.

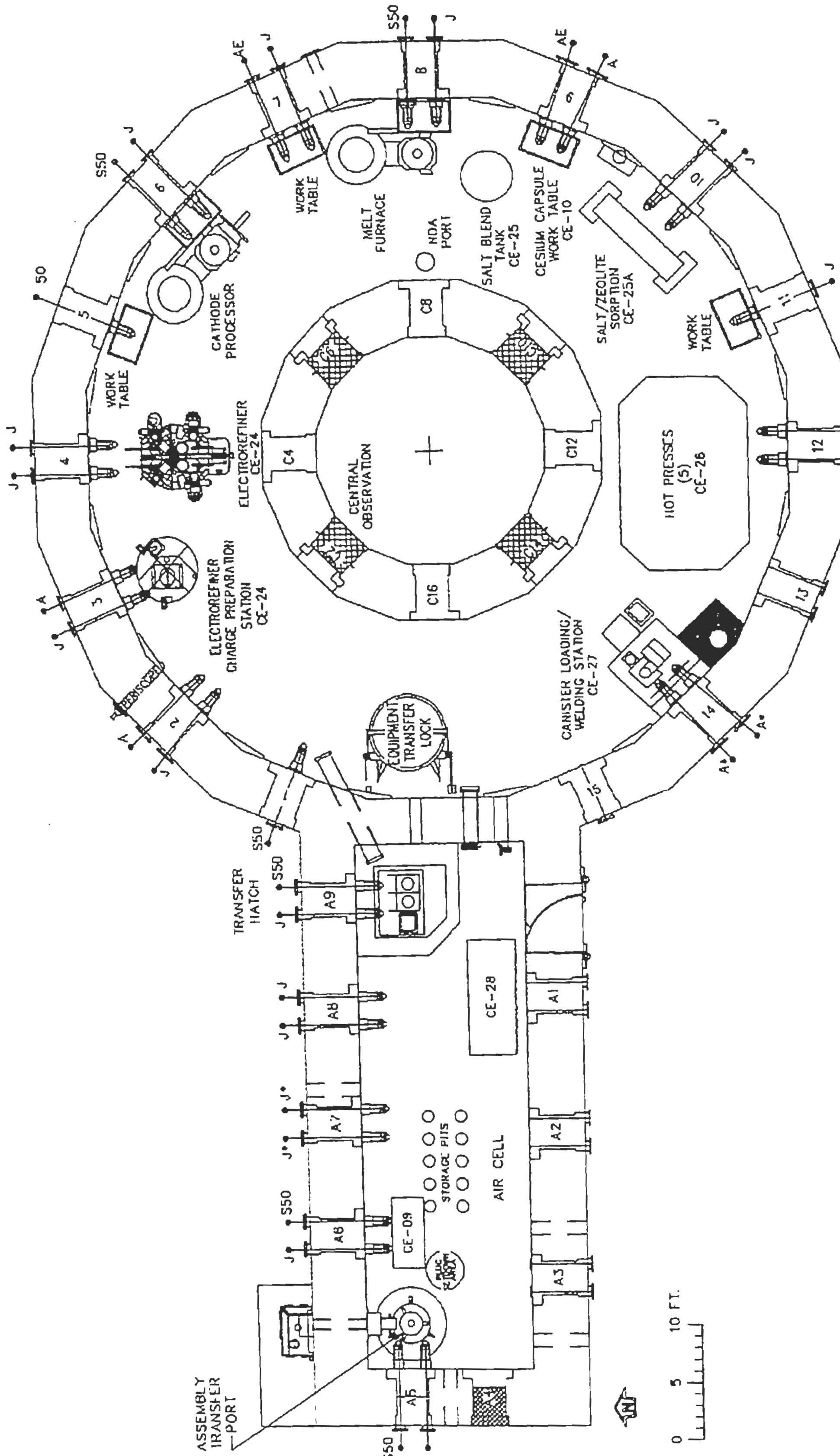
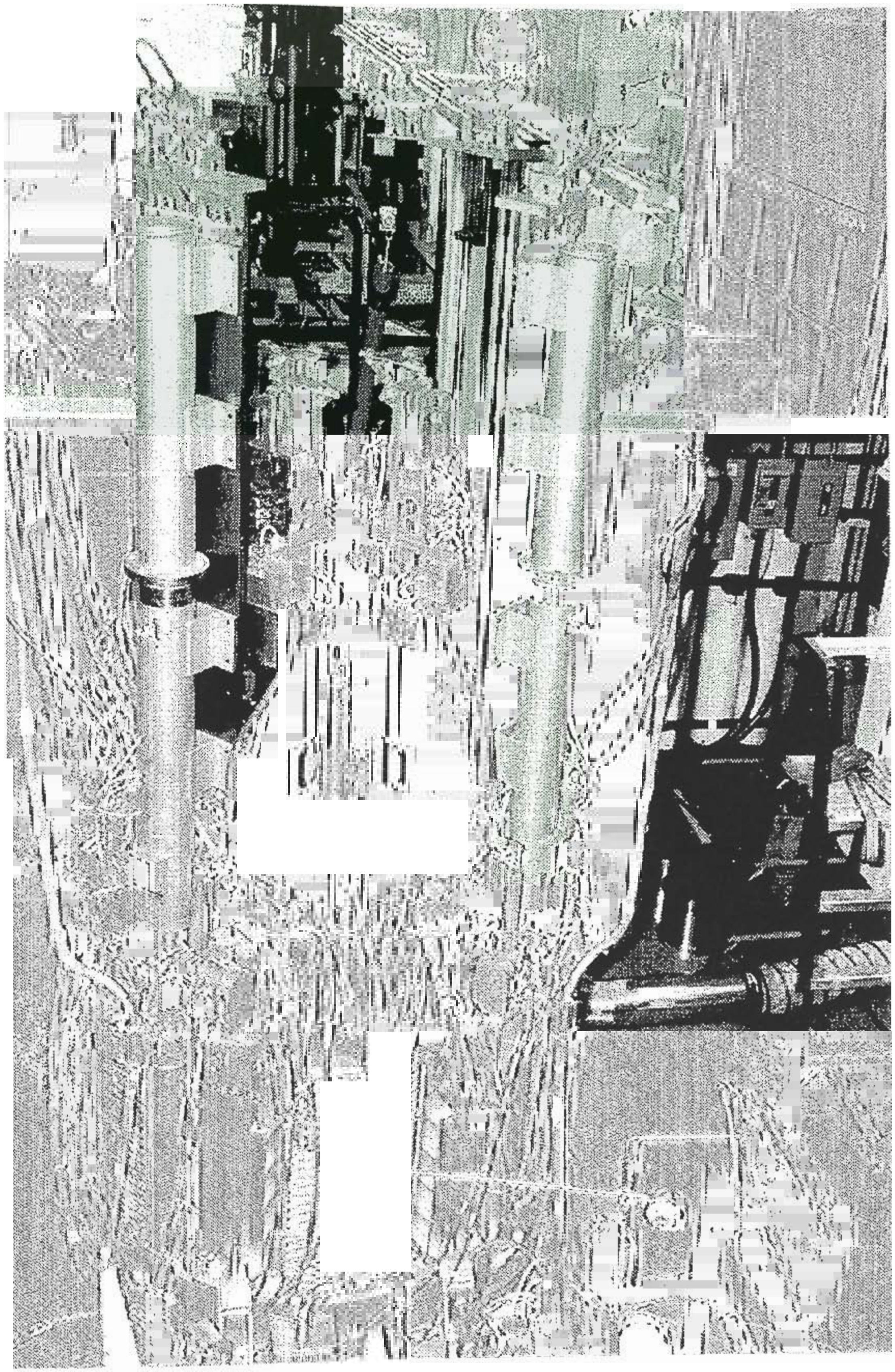


Figure 2-10. Plan view of the FCF and the argon cells, showing layout of the actini
casting equipment.



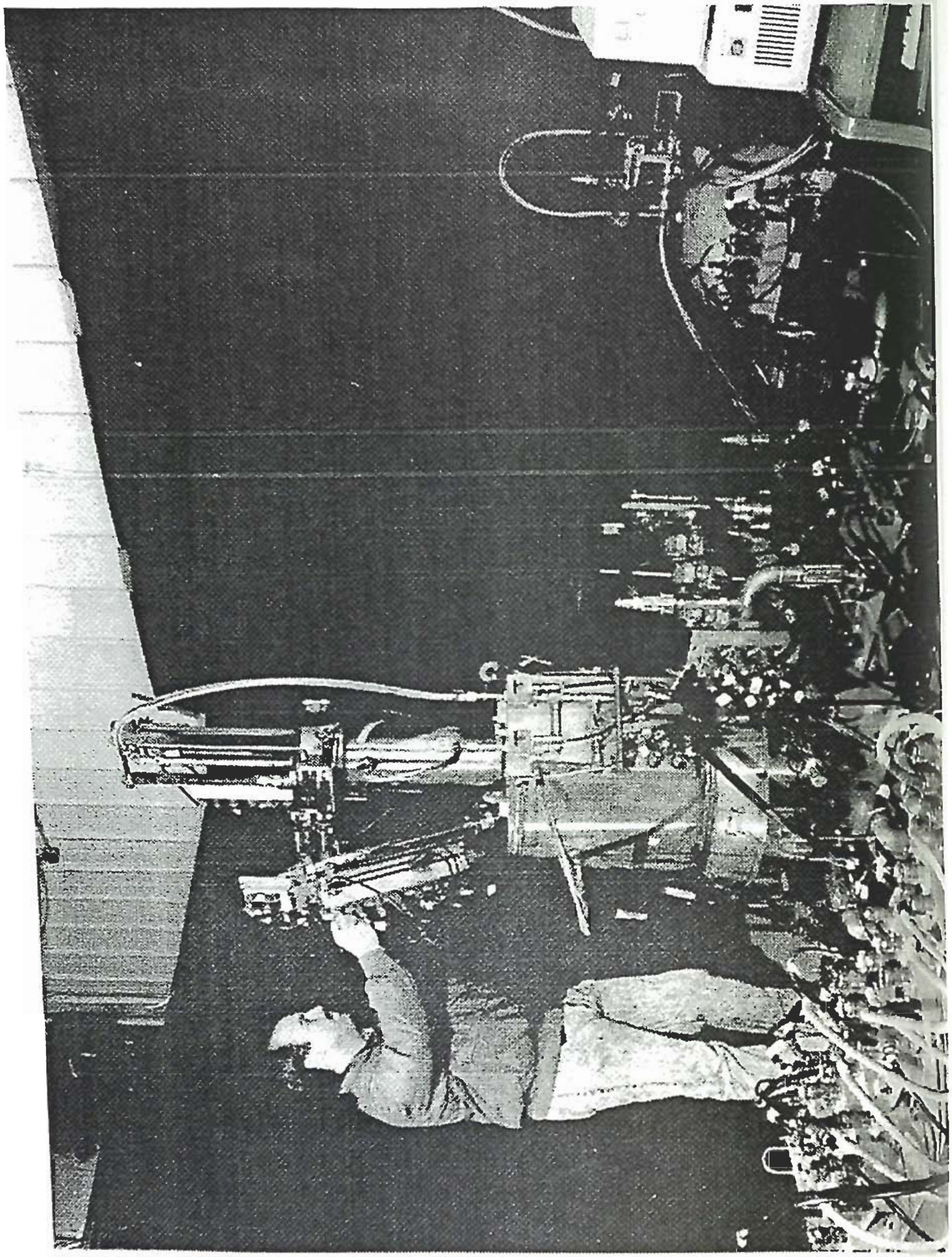
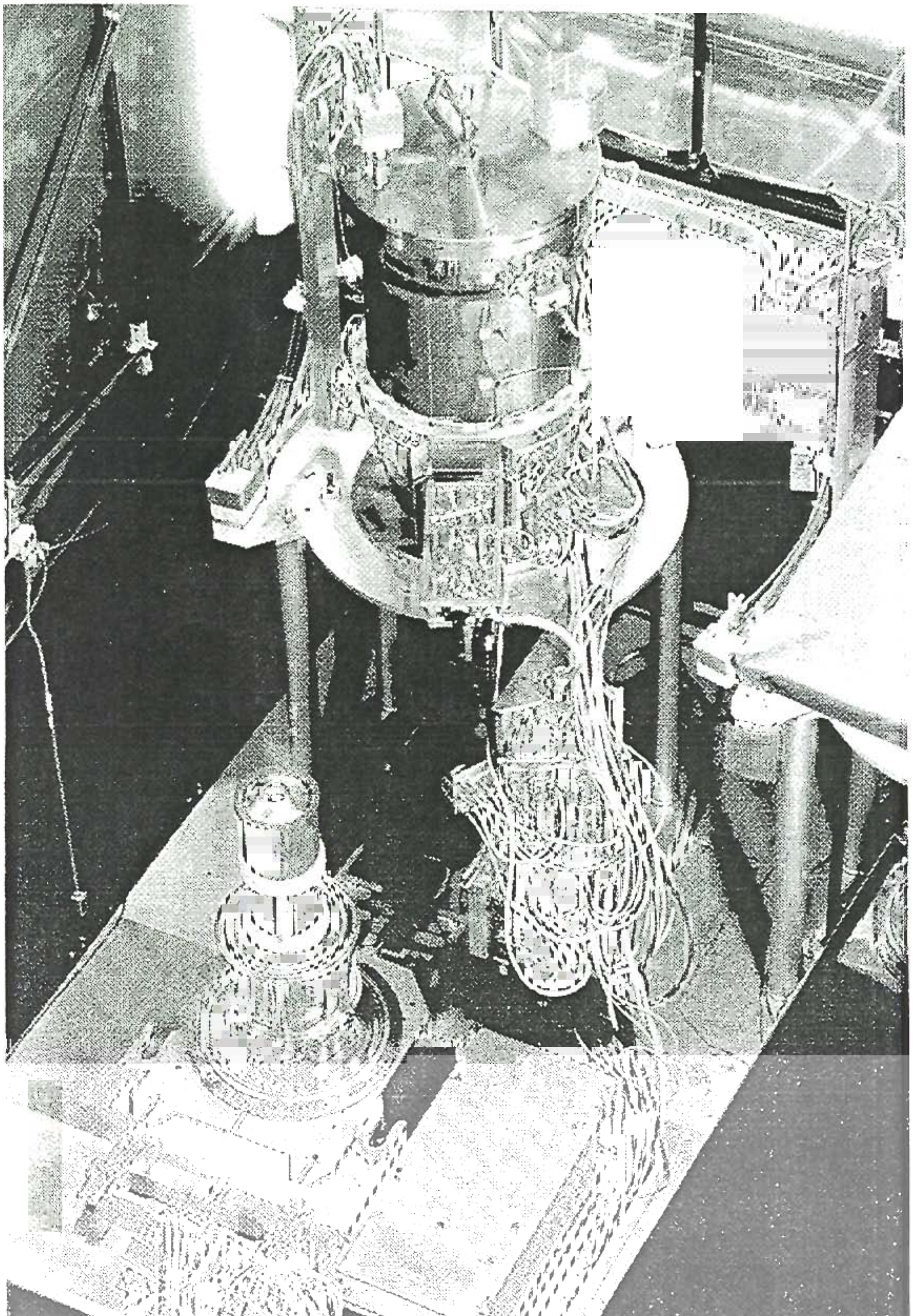


Figure 2-12. Casting furnace.



HFEF. The Hot Fuel Examination Facility is capable of handling large, highly radioactive objects such as spent fuel assemblies from a commercial Light Water Reactor (LWR). Figure 2-14 is the layout of the major equipment in HFEF involved in spent fuel processing. The layout of the major support systems in HFEF is presented in Figs. 2-15 through 2-17. An elevation section is shown in Fig. 2-18.

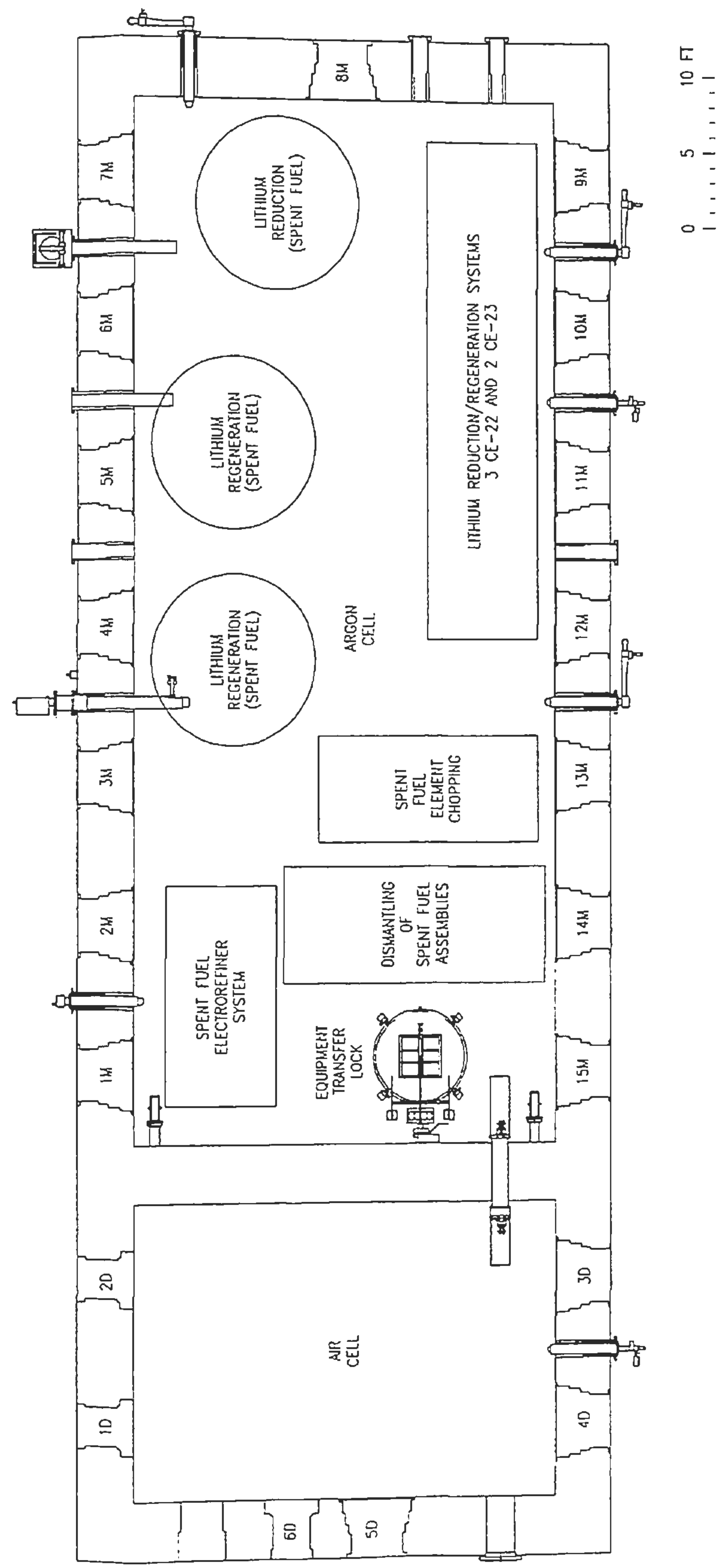
HFEF, completed in 1972, was constructed as a facility for the examination of experimental reactor fuels. Although HFEF is currently operational, the present SAR, ORR, and CHCS may require upgrades to meet modern DOE standards. Only minor modifications are expected to be necessary to bring the facility into full compliance with up-to-date standards for a Hazard Category 2 facility. In the preferred option, weapons-grade plutonium would not be brought into HFEF. If this facility were to be used for processing spent fuel, a fission-gas recovery system would be needed; it would be a commercial cryogenic system that would be added to the existing argon purification system.

ZPPR. ZPPR, completed in 1969 and was constructed as a facility for determining the physics parameters of reactor cores that used various materials, including ton quantities of plutonium. ZPPR has been inactive since 1992. The present SAR, ORR, and CHCS must be assessed and upgraded to meet safety standards appropriate to its new use and hazard classification. No major modifications are expected to be needed in order to meet modern standards for storage of plutonium, provided such storage is in sealed containers. There is an analytical laboratory in Building 776 fully equipped to support the immobilization activities. It has an analytical hot cell with plutonium containment to handle fully radioactive samples, and was upgraded in 1993 to meet current DOE orders.

RSWF. The Radioactive Scrap and Waste Facility provides temporary storage of radioactive and hazardous wastes. It is a Resource Conservation and Recovery Act of 1976 (RCRA) Class B facility. The Radioactive Waste Management Center (RWMC) at INEL is also available for interim waste storage.

2.2 Design Safety

FCF. The FCF design has been shown to withstand natural phenomena (earthquake, wind, flood, and volcanic) appropriate to a performance goal of an annual probability of exceedance of 10^{-5} per year, in accordance with DOE Order 5480.28 and DOE-STD-1020-94. Such performance goals are appropriate for facilities classified hazard category 1 in accordance with DOE-STD-1027-93, although FCF is only hazard Category 2 based on its current program.



;ure 2-14. Plan view of HFEF, showing layout of equipment for treating spent fuel.

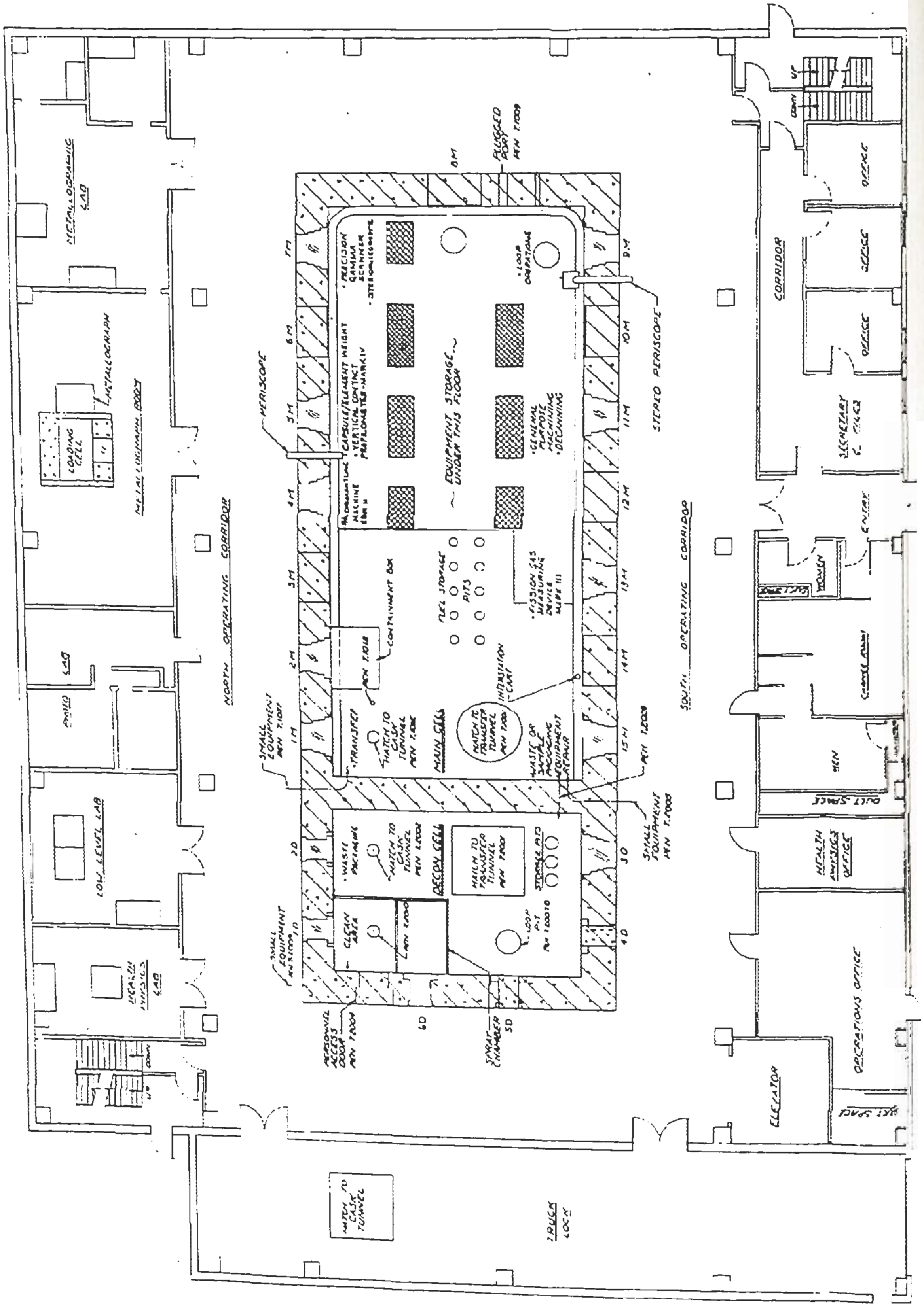


Figure 2-15. Plan view of the HFEF operating floor, showing the support systems.

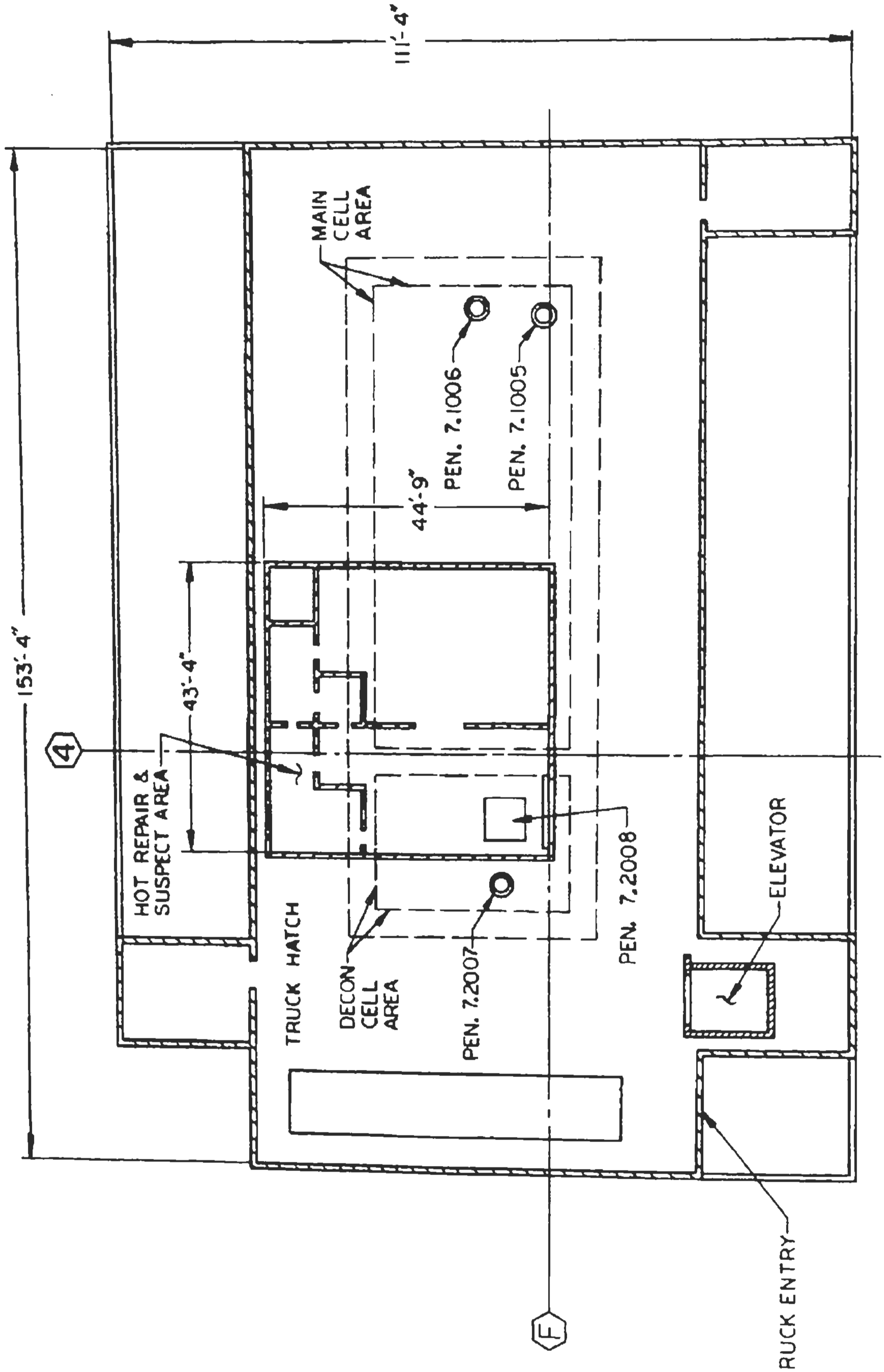


Figure 2-17. Plan view of the HFEF high-bay area, showing the support systems.

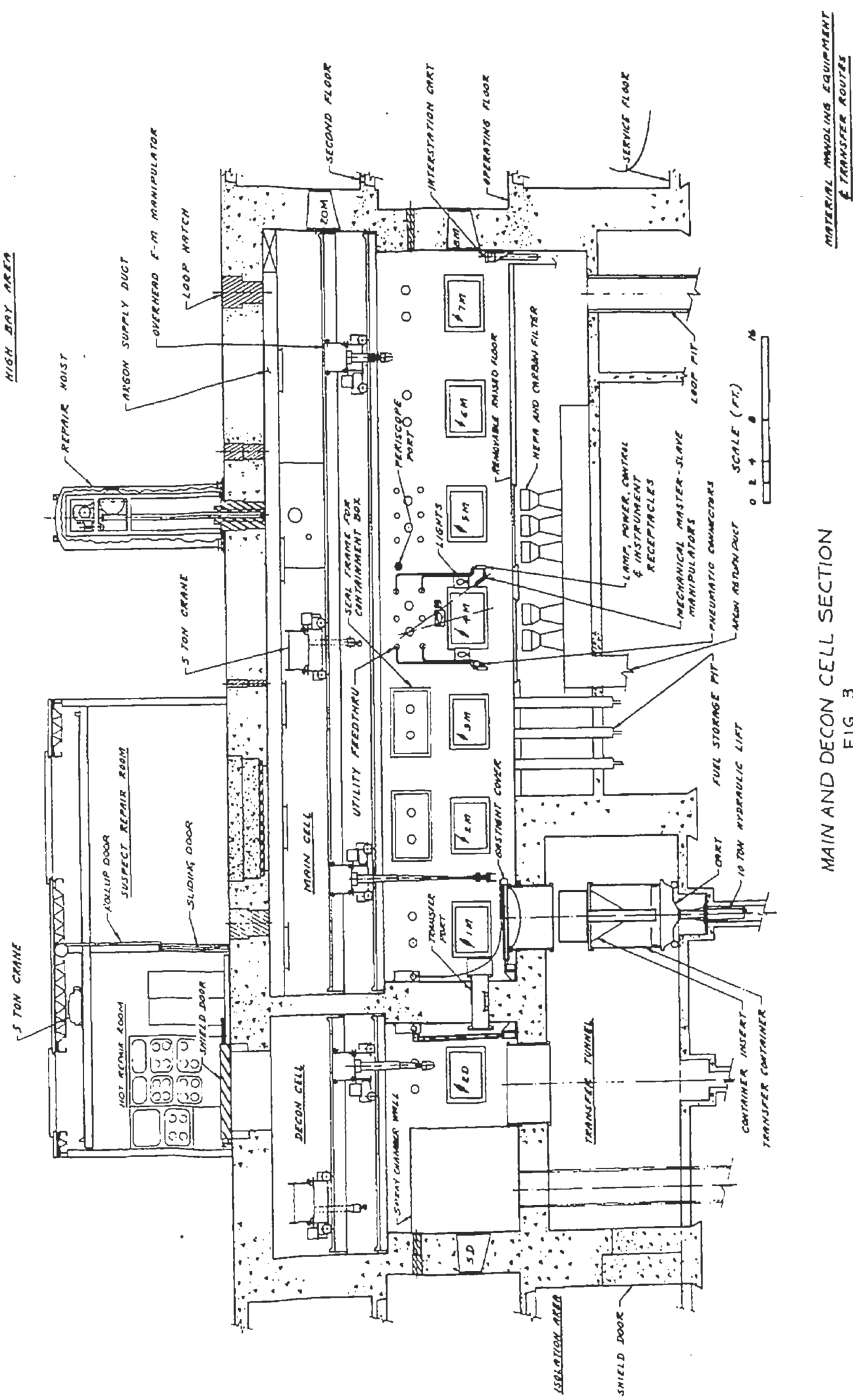


Figure 2-18. Elevation section of the cells, HFEF.

ZPPR. The ZPPR cell and fuel storage vault in Bldg. 776 will be used for temporary storage of incoming fissile materials. A layout of this complex as it currently exists is shown in Fig. 2-6. The facility is divided into (1) an area under an earthen mound where all fissile materials will be stored and (2) the support wing that contains the room with monitoring and control instruments, offices, and other support systems. The reactor cell, which currently houses the Zero Power Reactor is a 15.2-m (50-ft-diam) circular room with floor and walls of reinforced concrete. An air system (Fig. 2-19) that once provided cooling for the critical facility and maintained a negative pressure relative to the surroundings will be used for the following: (1) to maintain a negative pressure in the two storage areas, and (2) to provide cooling for product ingots with high gamma or neutron emissions. Because of its unique design, natural phenomena are not expected to challenge the integrity of the ZPPR facility.

HFEF. The HFEF may be used for temporary storage of product waste forms. While modern natural-phenomenon hazard assessments have not been completed for HFEF, no major upgrades are expected to be needed to bring the facility into compliance with current standards for a Hazard Category 2 (Cat 2) facility. HFEF was assessed against modern seismic criteria as part of a validation of DOE seismic walkdown procedures, and no major problems were identified.

2.2.1 Earthquake

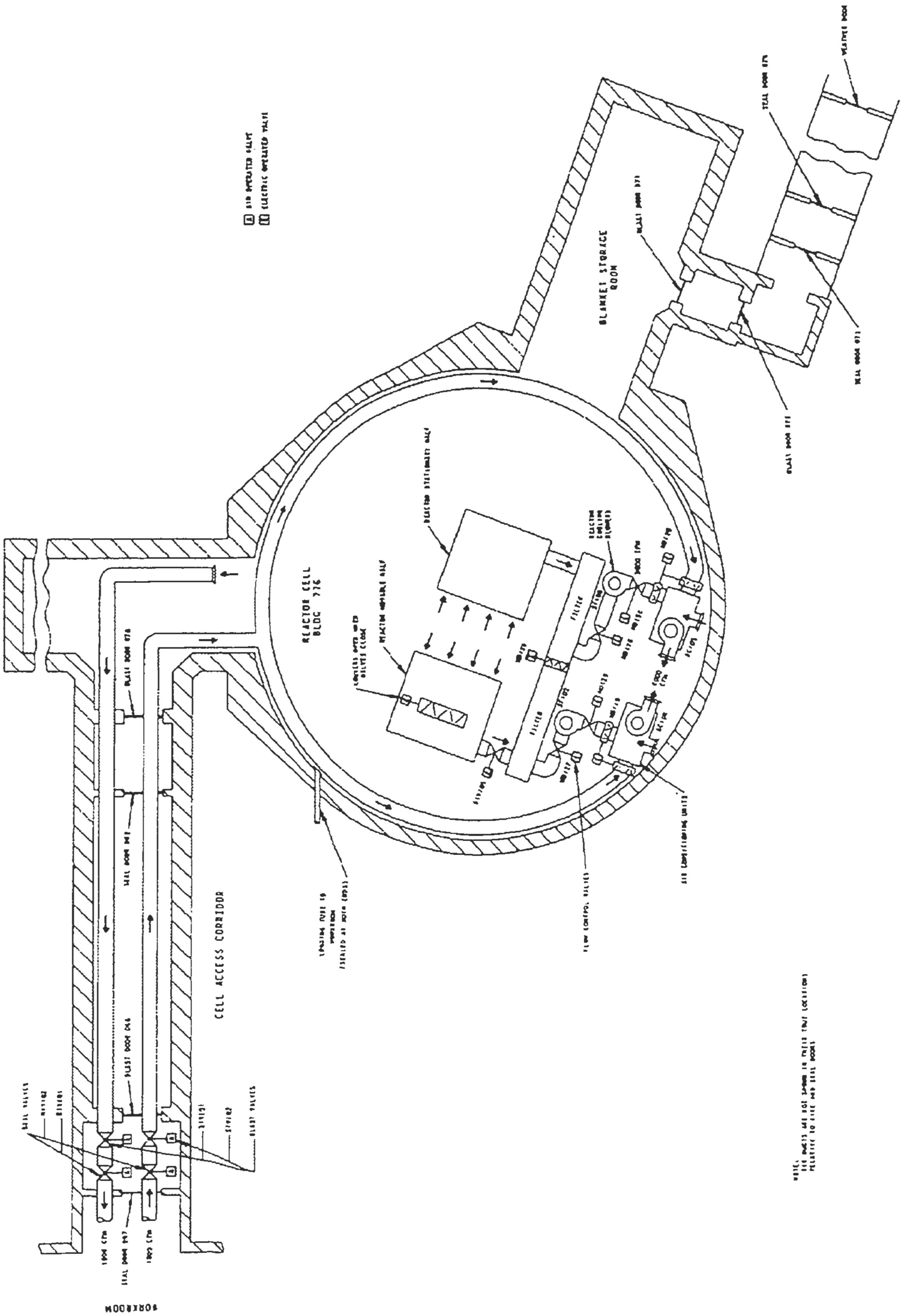
FCF. The FCF exceeds the requirements for a "moderate hazard" facility, which must withstand an earthquake with a zero-period ground-surface acceleration of 0.14 g in the horizontal direction. To achieve a more conservative goal, the seismic loading used for all but one of the existing buildings is based on a design seismic response spectrum with a zero-period ground-surface acceleration of 0.21 g in the horizontal direction.

SEB. The conservative-design seismic-response spectrum for the Safety Equipment Building is based on a design seismic response spectrum with a zero-period ground-surface acceleration of 0.24 g in the horizontal direction.

ZPPR. In the ZPPR facility, the design of the reactor cell is based on two criteria: (1) "Zone 2" earthquake susceptibility (0.2 g), and (2) the ability to withstand a 520 kPa (75-psi) internal cell pressure. The strength of the support structure needed to hold the earth mound and gravel/sand roof exceeds the strength required to withstand the earthquake effects in a "Zone 2" area.

2.2.2 Wind

The tornado risk at INEL is sufficiently small that wind loading is controlled by straight winds. The design-basis wind for the FCF is 150 km/h (95 mph).



gure 2-19. Airflow patterns in ZPPR reactor cell.

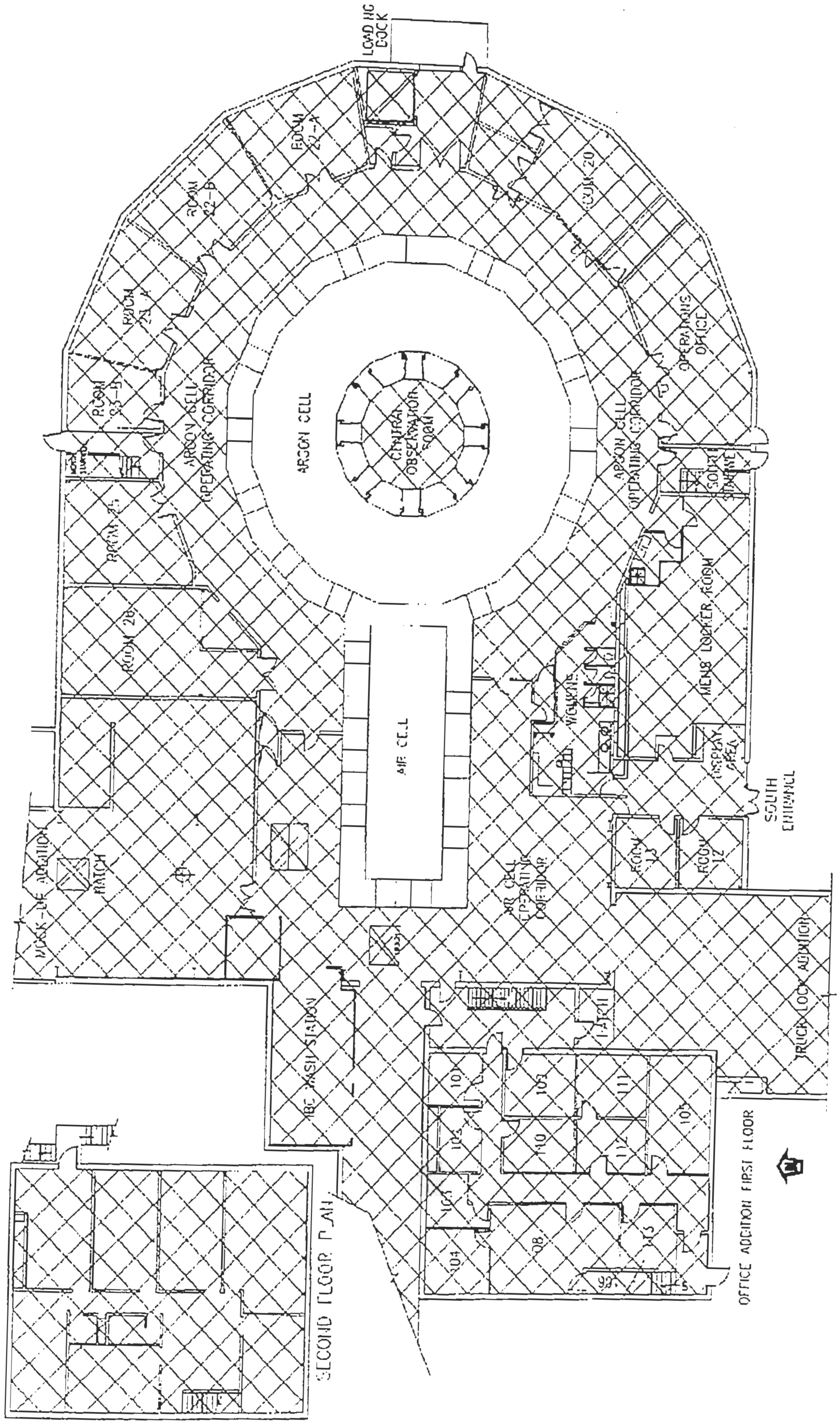


Figure 2-20. Fire sprinkler coverage of the FCF operating level.

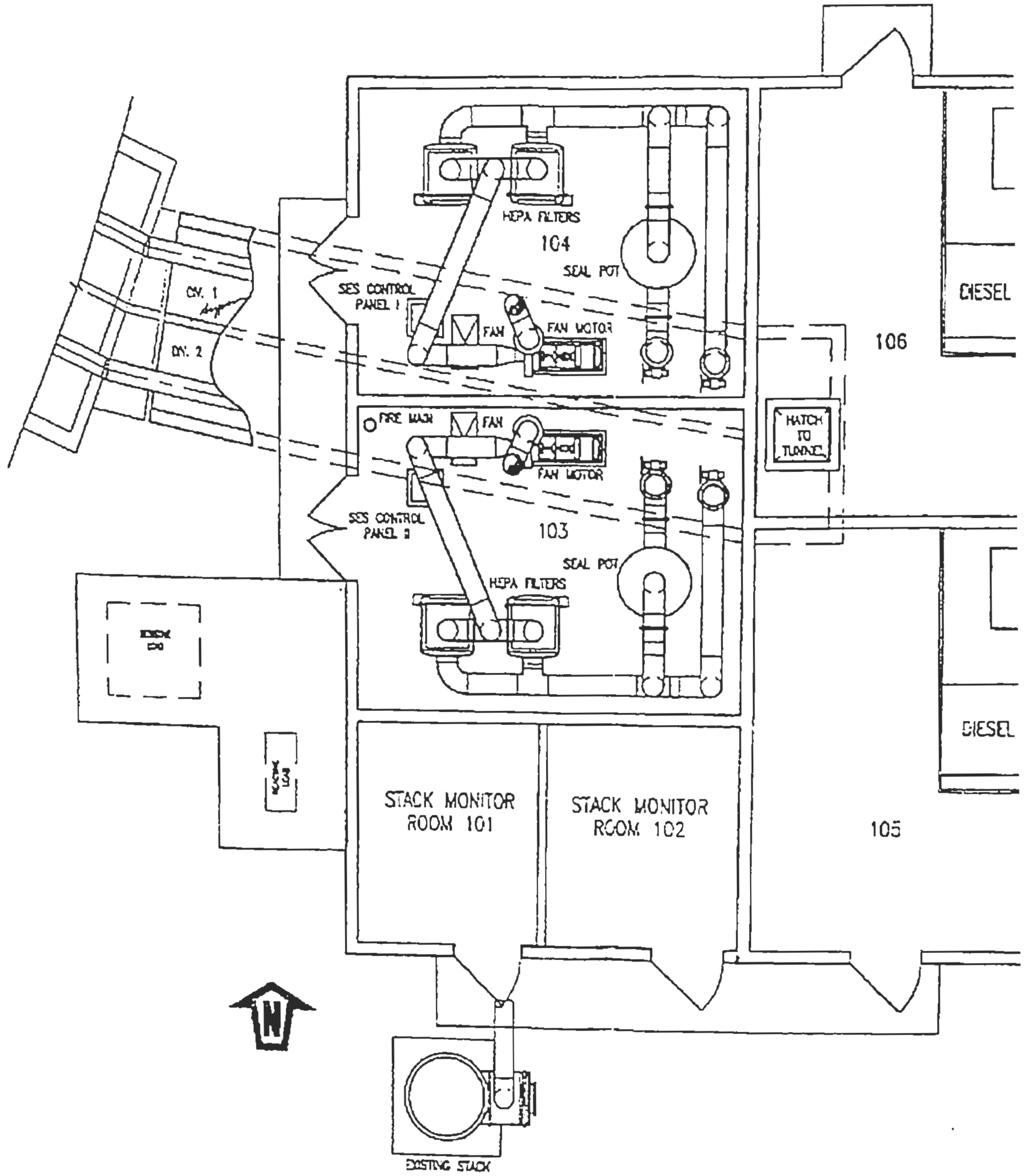


Figure 2-21. Layout of the Safety Equipment Building.

ZPPR. The major safety systems for ZPPR are: (1) a HEPA-filtered normal exhaust system for the plutonium storage vault and the adjacent work areas; (2) an emergency exhaust system for the vault and adjacent handling area consisting of a sand filter backed by a HEPA filter; (3) a sand/gravel roof filter, 16 ft thick (4.87 m), for the concrete cell backed by a HEPA filter and capable of withstanding large overpressures; (4) double-isolation seal valves for the cell and workroom; and (5) highly sensitive plutonium air and personnel egress monitors.

HFEF. The primary safety system for HFEF consists of the following: (1) the steel-lined argon-cell confinement including the steel-lined cell, the active-transfer locks, and the passive penetrations; and (2) the argon-cell atmosphere system, which maintains a negative pressure differential between the cell and the building. Defense in depth is provided by two additional HEPA-filtered air-exhaust systems that maintain contamination control: (1) a double-filtered system serves contaminated areas, and (2) a single-filtered system serves the remainder of the building. Administrative controls also provide defense in depth. Facilities for repair of contaminated equipment, handling radioactive liquid waste and transfer of casks and containers are available.

Safety-Class I&C, Electrical, and Monitoring Systems. Radiation protection for FCF meets ALARA goals in accordance with DOE Orders 5480.11 and 6430.1A. Protection against asphyxiation is addressed in the design, the monitoring systems, and the operating procedures. Radiation and asphyxiation protection in HFEF and radiation protection in ZPPR are addressed by the design, the monitoring system, and the operating procedures in a manner similar to FCF.

FCF uses a dual-train, DBE-qualified, stack-monitoring system that incorporates the latest developments in air and gamma monitoring. All releases through the 61-m (200 ft) stack are recorded.

The backup power system provides emergency power to FCF for up to 3.5 days without refueling when preferred power is not available. It consists of two independent diesel-generator systems that have been designed, constructed, and qualified to survive a DBE and to meet critical equipment standards. Both are housed in the SEB and are separated by three-hour fire barriers. Each system has a 320-kW diesel-driving generator capable of continuously supplying 480-V, 3-phase power to critical systems including the building exhaust system, the air-cell exhaust system, selected radiation monitors, the confinement differential pressure monitors, the uninterruptible power systems, and, as required, the interbuilding cask (IBC) cooling blower.

2.2.6 Nuclear Criticality

The Criticality Hazards Control Statement (CHCS) for the FCF has been approved by DOE for operations encompassing the Electrometallurgical Treatment of spent nuclear fuel. That document specifies the criticality limits, requirements, and safety basis for handling fissionable material in FCF; it was prepared in accordance with DOE Order 5480.24, "Nuclear Criticality Safety."

The immobilization of weapons-grade plutonium is within the scope of the current FCF-CHCS, so that no additional criticality safety concerns are raised. Moreover, the FCF criticality limits, requirements, and safety basis can easily be incorporated into the CHCS of other ANL-W facilities (e.g., HFEF). Thus, it is envisioned that only minor revisions to the current FCF-CHCS or the HFEF-CHCS are needed to satisfy DOE nuclear criticality requirements for operations involving the immobilization of weapons plutonium in either or both hot cells. The key elements of the nuclear criticality safety program at FCF are summarized below.

Criticality events during immobilization activities will be prevented by a safety program similar to that currently in place. Because of the required facility throughput, a criticality safety program based on single-parameter limits such as minimum critical mass or radius is not feasible. Criticality control during immobilization operations will be achieved by the integration of criticality safety analysis, equipment design, the accountability program, administrative procedures for operations, and the computerized Mass Tracking System (MTS), which is operational.

Criticality control is based on physical controls to the maximum extent possible because physical controls provide an inherent, passive form of control. The laws of physics and chemistry provide one set of physical constraints, which is independent of human activity. Mechanical design features that physically limit or control the amounts and configurations of materials in process equipment and containers provide a second set of passive constraints on operations. Addition of neutron absorbers to the immobilization product may be required to assure criticality safety during the immobilization and temporary storage operations at ANL-W, although there may be requirements for absorbers to assure subsequent prevention of criticality in long-term storage elsewhere.

A neutron absorber, such as gadolinium, will be incorporated into the zeolite along with plutonium to prevent criticality after emplacement. The gadolinium will be added, as a chloride, to the process upstream of the zeolite absorption step. The chemical and ion exchange behavior of gadolinium in the zeolite is very similar to that of plutonium. The zeolite sites occupied by gadolinium and plutonium are identical; therefore, both elements will be uniformly distributed in the glass-bonded zeolite waste form. The behavior of these elements in the geological medium after leaching should be similar for any of the proposed waste forms (glass, ceramic, or glass-bonded zeolite).

Process equipment, containers that interface with process equipment, storage containers, and storage racks are designed to meet specific criticality safety criteria. These criteria include limiting the types of materials that can be placed in containers or equipment, limiting the geometric configuration of process material or containers, and limiting the interaction between adjacent containers or equipment items. Nuclear criticality analysis is used to confirm that final designs of equipment, containers, and racks provide adequate criticality controls.

The MTS is interrogated prior to any transfer of controlled material between zones, to ensure that criticality safety limits are not exceeded in the destination zone. For the same reason, the MTS is also interrogated prior to any transfer of a controlled process material between containers. An error message is generated if the proposed transfer violates criticality safety limits. If the proposed transfer is acceptable, the MTS produces the electronic forms required to proceed with and document the transfer.

The final aspect of criticality control in the facility is an ongoing program of criticality safety analysis. An analysis is performed for each operation, each container, and each piece of process equipment of potential significance for criticality safety. Any proposed change to equipment design, container design, or operating strategy is analyzed before the change is implemented.

Single-parameter limits are too restrictive for the required throughput, as is the case for Electrometallurgical Treatment of EBR-II spent-fuel operations. To achieve the required batch sizes, a detailed, mechanistic analysis is performed for each step of each operation. For each operation, all credible abnormal events are identified and placed in one of five categories. Each event in each category is then classified as unlikely or extremely unlikely according to the number of physical and procedural barriers that reduce the probability of occurrence of that event.

The criticality safety criterion adopted for the analysis is that criticality shall not result from the concurrent occurrence of one unlikely event and one extremely unlikely event from different event categories. The KENO V.a criticality analysis code was used to verify that this criterion is satisfied for each credible combination of two abnormal events. KENO V.a was also used to determine the maximum acceptable batch size for each operation.

DOE Order 5480.5 requires criticality alarm systems to be installed in all locations where quantities of fissionable material may exceed 700 g (24.7 oz) of ^{235}U, 520 g (18.3 oz) of ^{233}U, 450 g (15.9 oz) of plutonium, or 450 g (15.9 oz) of any combination of these materials, unless the physical form and composition of the fissionable material justifies exceeding these limits. ANSI/ANS 8.3 states that a monitor is required in areas accessible to people, where, if a criticality event occurs, the maximum foreseeable dose in free air would exceed .12 Gy (12 rad).

Based on this requirement, criticality monitors are located in FCF in the radioactive liquid waste room, central observation room, high-bay areas, and decontamination operations area. Because of limited shielding surrounding the liquid waste tanks, personnel in the radioactive liquid waste room could receive a dose greater than .12 Gy (12 rad) in the event of a criticality incident. Personnel in front of cell windows in the argon cell could receive a dose greater than .12 Gy (12 rad) if a criticality occurred in the argon cell. Consequently, a criticality monitor is located in the central observation room to detect a criticality incident in the argon cell. A criticality monitor in the high-bay area monitors the air cell and the high-bay/truck-lock area. The spray chamber and suited-entry repair area are also monitored.

Detector locations are chosen to avoid the effects of shielding by massive equip and other materials. Detectors in the radioactive liquid waste room are placed so they can monitor all the tanks with minimal shielding between the tanks and dete The other three monitors are shielded by windows. The alarm set points of these monitors are adjusted to account for the windows.

In summary, the immobilization of weapons plutonium by electrometallurgica treatment is within the scope of the current FCF-CHCS, and no additional critical safety concerns are raised. Moreover, the FCF criticality limits, requirements, and basis can easily be incorporated into the CHCS of other ANL-W facilities as requi is envisioned that only minor revisions to the current CHCS are needed to satisfy nuclear criticality requirements for operations involving the immobilization of we plutonium.

2.2.7 Ventilation

The immobilization processes will be carried out in FCF with material handlin front-end processes performed in FMF, ZPPR, and HFEF. The existing Balance of Facilities (BOP) systems in FCF, HFEF, FMF, and ZPPR, such as steam, instrumen plant air, and potable and process water, are adequate to support the processing storage activities involved in this immobilization project.

The release of radioactivity to the environment is controlled by multiple physi barriers and a safety-grade exhaust system to prevent uncontrolled releases from unlikely breach of these barriers. The first barrier is the process equipment, whic designed to contain spills and process upsets, and is maintained at a negative pre relative to the cell. The next barrier consists of the steel-lined, reinforced concrete of the air and argon cells.

A general layout and elevation of FCF showing the main support systems are presented in Figs 2-7 through 2-9. The Hot Repair Area (Fig. 2-22) located below cell has facilities for decontamination of cell equipment and for both remote and maintenance. The air and argon cells and the Safety Equipment Building are nuc safety-class structures designed to meet DOE General Design Criteria for seismic and tornado events. The two hot cells and areas under the cells, such as the trans tunnel and hot repair area, are Level-1 contaminated areas; the areas surroundin cells are Level-2 potentially contaminated; the office areas are Level-3 noncontam Air flows are from outside the structure into Level 3 through Level 2 to Level 1.

Air circulation. The FCF has three independent exhaust systems as shown in Fig. 2-23: (a) building, (b) air cell, and (c) safety. The three systems develop the pressure gradients necessary to prevent the spread of radioactive material from contaminated or potentially contaminated areas to clean areas. Nominal differen pressures for the facility are indicated in Fig. 2-24. The building and air-cell exha systems maintain radioactive areas such as the air cell, subcells, transfer tunnel, repair area negative with respect to nonradioactive areas. The FCF building sup flows are shown in Fig. 2-25.

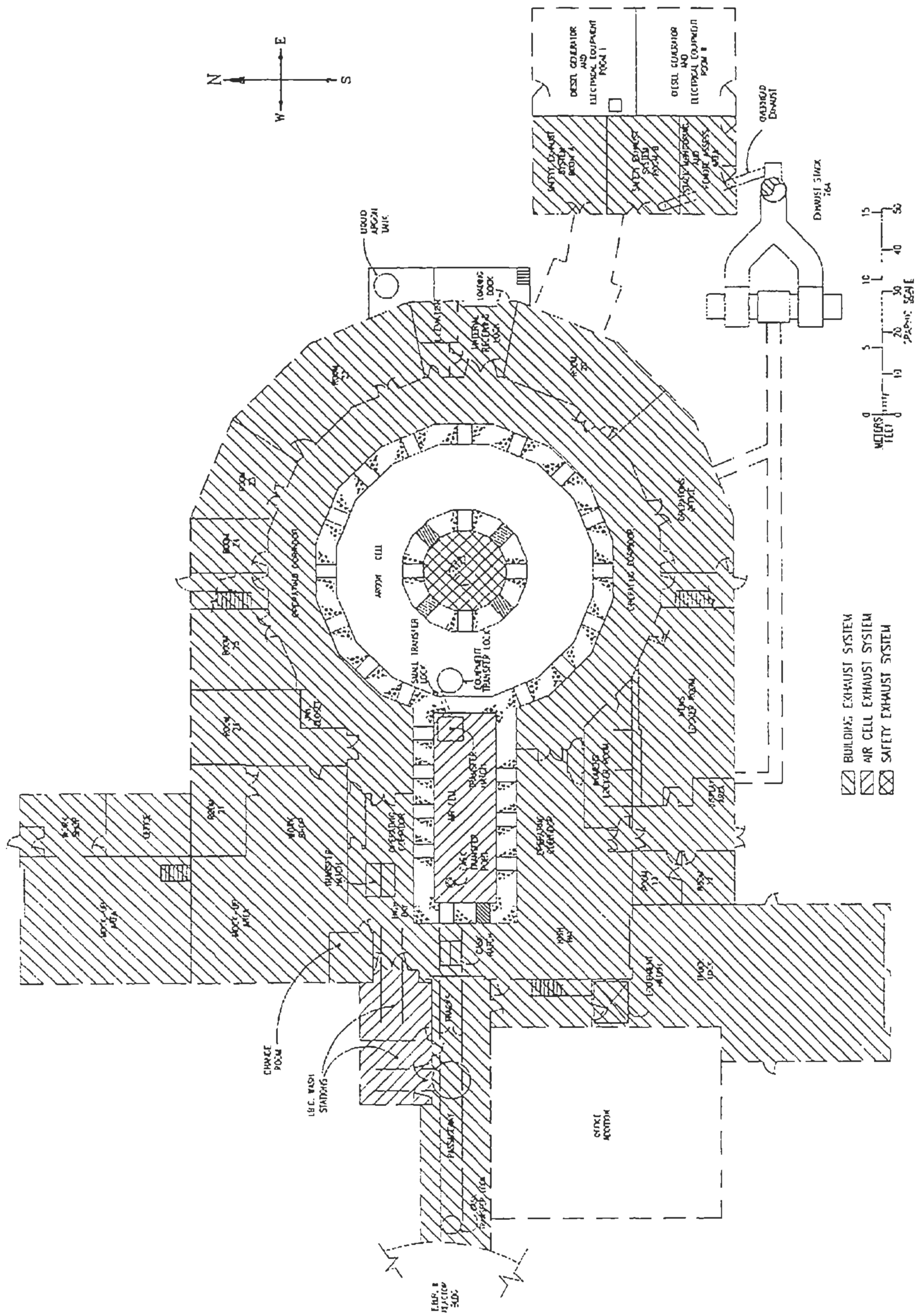


Figure 2-23. FCF exhaust system zones.

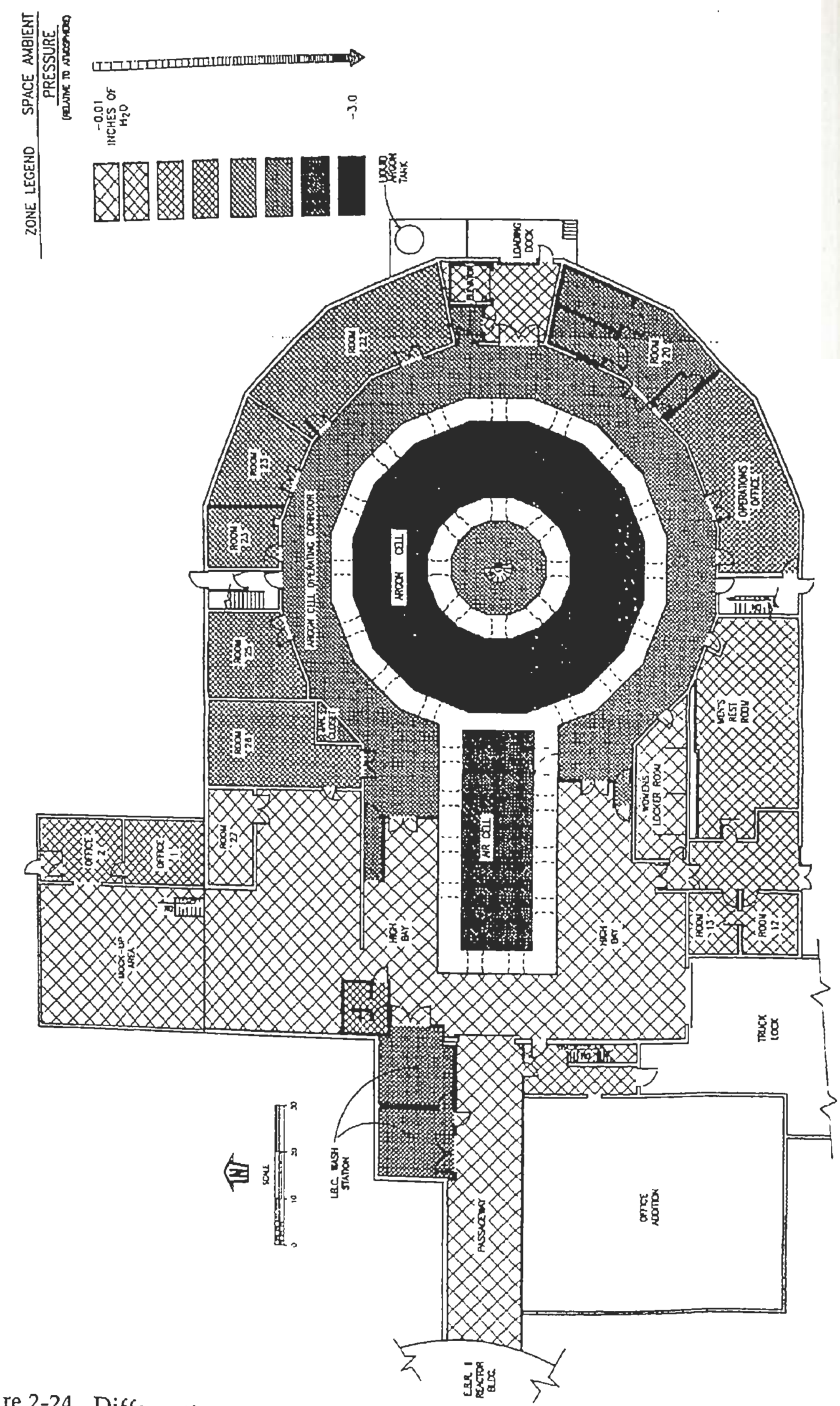


Figure 2-24. Differential pressure zones on the FCF operating level.

Argon circulation. The FCF and HFEF have independent systems for recirculating and purifying argon from the two argon cells. The argon systems remove heat generated by in-cell lighting, process equipment, and radioactive decay. By controlling the temperature of the argon gas, the system maintains the cell atmosphere at a pressure below ambient atmospheric pressure. This negative gauge pressure prevents out-leakage of radioactive/contaminated gas to the operating areas.

In addition, the pressure in the argon cell is maintained by its closed-loop purification system, which recirculates cell gas through a purification bed to do the following: remove water and oxygen, remove heat (mainly from cell lighting), and maintain cell pressure. The cell atmosphere is argon with less than 5% nitrogen and less than 50 ppm of water and oxygen. Pressure in the argon cell is maintained by controlling the cooling of the cell atmosphere, with excess gas vented to the air-cell exhaust through a charcoal bed and multiple HEPA filters. A low argon inventory in the cell is corrected by two banks of five argon gas cylinders through the emergency argon supply system.

The argon cell recirculation system for the FCF consists of two subsystems or loops. Each individual recirculation loop consists of an assembly of inlet HEPA filters in the argon cell, a cooling box, and a circulation fan. The argon gas from the cell is drawn through the HEPA filters and then through ducts to a cooling box that contains a bank of direct Freon-expansion cooling coils with a capacity of 330,000 BTU/hr. From the cooling box, the argon gas goes through a totally enclosed circulation fan with a capacity of 340 m^3/min (12,000 scfm) and back to the argon cell. A line from the discharge of the recirculation fan of the cooling loop circulates a small amount of gas through the argon purification loop outside the cell for oxygen and water removal and returns it to the inlet side of the cooler. The coolers are two self-contained automatic unloading, reciprocating refrigeration compressor units with interconnected piping to service either or both sets of cooling coils.

The HFEF has a similar system for recirculating, cooling, and purifying the argon cell atmosphere. Since spent fuel will be processed in the preferred option, the fission gases, tritium, krypton, and xenon, will be released into the cell. Tritium is removed as water by the existing purification equipment for removing oxygen and water. Commercial cryogenic equipment will be added to separate krypton and xenon and to compress the concentrated gases for storage in cylinders. The intake to the cryogenic system will be downstream of the oxygen/water removal system. No fission-gas removal equipment is required in FCF for immobilization operations, because no materials containing fission gas will be involved in those FCF operations.

2.3 Safeguards and Security

Special Nuclear Material classification is affected by the quantity of fissile material and the Attractiveness Level. The DOE defines the attractiveness level of nuclear material through a categorization of types and compositions that reflects the relative ease of processing and handling required to convert that material to a nuclear explosive device. Table 2-3 comes from the DOE Order for *Control and Accountability of Materials* (5632.33B) dated 9-7-94.

The level of protection accorded to an attractiveness level is dependent on the quantity or concentration of the material. Each category of protection has its own requirements ranging from the highest level of protection, Category I, for assembled weapons, to Category IV for irradiated forms and less than 3 kg (6.6 lb) of low-grade material. Protection of the material is accomplished through a graded system of deterrence, detection, delay, and response as well as material control and accountability. Layers of protection may then be applied to protect material of greatest attractiveness within the innermost layer and with the highest controls. Material of lesser attractiveness does not require as many layers of protection and fewer controls.

ANL-W already has in place approved safeguards and security systems for the tonne quantities of weapons-usable plutonium located on the ANL-W site. These systems meet the DOE requirements for surplus weapons plutonium, which is defined

Table 2-3. (DOE) Nuclear Material Attractiveness and Safeguards Categories for Plutonium.

	Attractiveness	Pu/^{233}U category			
	Level	I	II	III	IV[a]
WEAPONS Assembled weapons and test devices	A	All Quantities	N/A	N/A	N/A
PURE PRODUCTS Pits, major components, buttons, ingots, recastable metal, directly convertible materials	B	≥2 kg (≥4.4 lb)	≥0.4 <2 kg (≥0.9 <4.4 lb)	≥0.2 <0.4 kg (≥.4 <9 lb)	<0.2 kg (<.4 lb)
HIGH-GRADE MATERIAL Carbides, oxides, solutions (≥25 g/L) nitrates, etc., fuel, elements and assemblies, alloys and mixtures, UF_4 or UF_6 (≥50% ^{235}U)	C	≥6 kg (≥13 lb)	≥2 <6 (≥4.4 <13 lb)	≥0.4 <2 kg (≥.9 <4.4 lb)	<0.4 kg (<.9 lb)
LOW-GRADE MATERIAL Solutions (1–25 g/L), process residues requiring extensive reprocessing, moderately irradiated material, ^{238}Pu (except waste), UF_4 or UF_6 (≥20% <50% ^{235}U)	D	N/A	≥16 kg (≥35 lb)	≥3 <16 kg (≥6.6 <35 lb)	<3 kg (<6.6 lb)
ALL OTHER MATERIALS Highly irradiated forms, solutions (≥1 g/l), uranium containing <20% ^{235}U (any form or quantity)	E	N/A	N/A	N/A	Reportable quantities

[a] The lower limit for category IV is equal to reportable limits in this Order

as Attractiveness Level "B", Category I SNM under the DOE graded safeguards system. The site is equipped with a vehicle control station for positive control of all vehicular traffic to and from the ANL facilities that are to be used for operations with Category 1 material.

Currently Level "B" Category 1 material is stored in the ZPPR vault. This is a Materials Access Area (MAA) located within a Protected Area (PA). Security fencing, intrusion detection devices, lighting and viewing, personnel access/egress control, and closed-circuit television (CCTV) surveillance are provided for physical security. Controls and systems are in place for transfers of Category 1 material to and from the ZPPR MAA. The FMF is a secure facility located within the protected area. The FMF work room areas are shown in Fig. 2-26.

The FCF Nuclear Material Control and Accountability Plan Addendum for Category 1 operations has been reviewed by DOE; its provisions fully meet the requirements of DOE Orders 5632.1C and 5633.33 and other applicable documents. Safeguards and security systems specified by that Addendum are in place, including controls and systems for transfers of Category 1 material to and from FCF. These Category 1 provisions would be extended to HFEF if required.

The FCF has special characteristics that facilitate safeguards and security measures. It contains highly radioactive material that generates a high radiation field inside the hot cell walls. Access to the interior of the cells is only by material transfer through special, remotely operated transfer ports that require electrical power to operate. Safeguards and security systems for Category 1 operations qualify the steel-lined reinforced concrete walls of the hot cell itself as the MAA boundary. There is no personnel access through this MAA boundary. Provisions for Category 1 operations include: alarms to provide remote indication of port use, remote surveillance by CCTV, remotely interlocked electrical power to operate ports, remotely interlocked electrical power to operate equipment for in-cell material transfer, and remote-reading instrumentation to detect breaching of the cell boundary. Personnel access/egress to operating corridors and transfer ports is controlled in accordance with PA requirements, and Category 1 material surveillance (MS) procedures apply.

The HFEF has similar characteristics to facilitate application of Category 1 safeguards and security provisions.

Near-real-time materials control and accountability is provided by the computerized MTS system to track the locations, masses, and compositions of fissionable materials. The MTS currently is operational in the FCF. The MTS is interrogated prior to any transfer of SNM within the facility, and automatically records the in-facility weighing measurements required for MTS approval of material transfers within the facility or across the facility boundary.

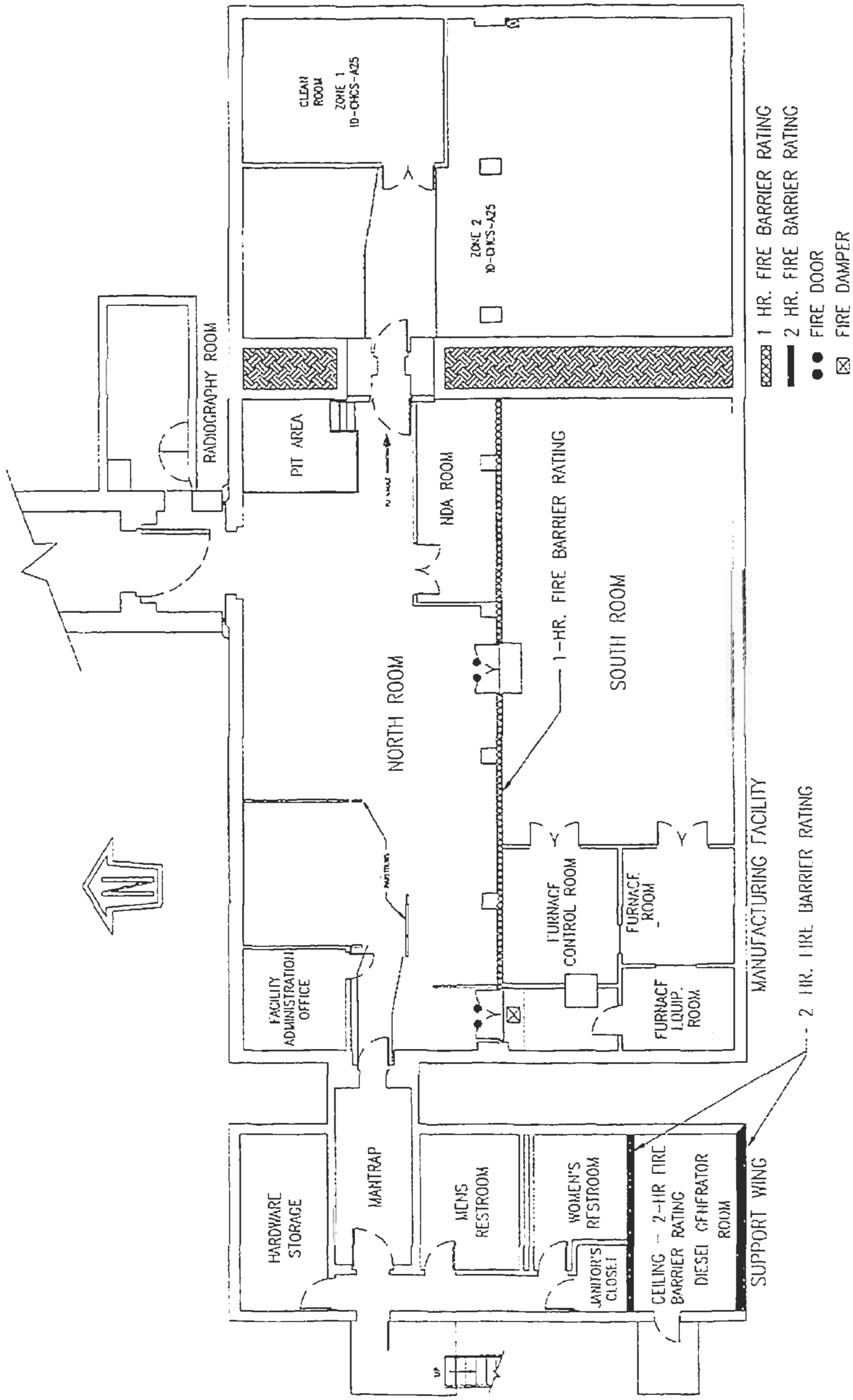


Figure 2-26. Building 704 FMF floor plan.

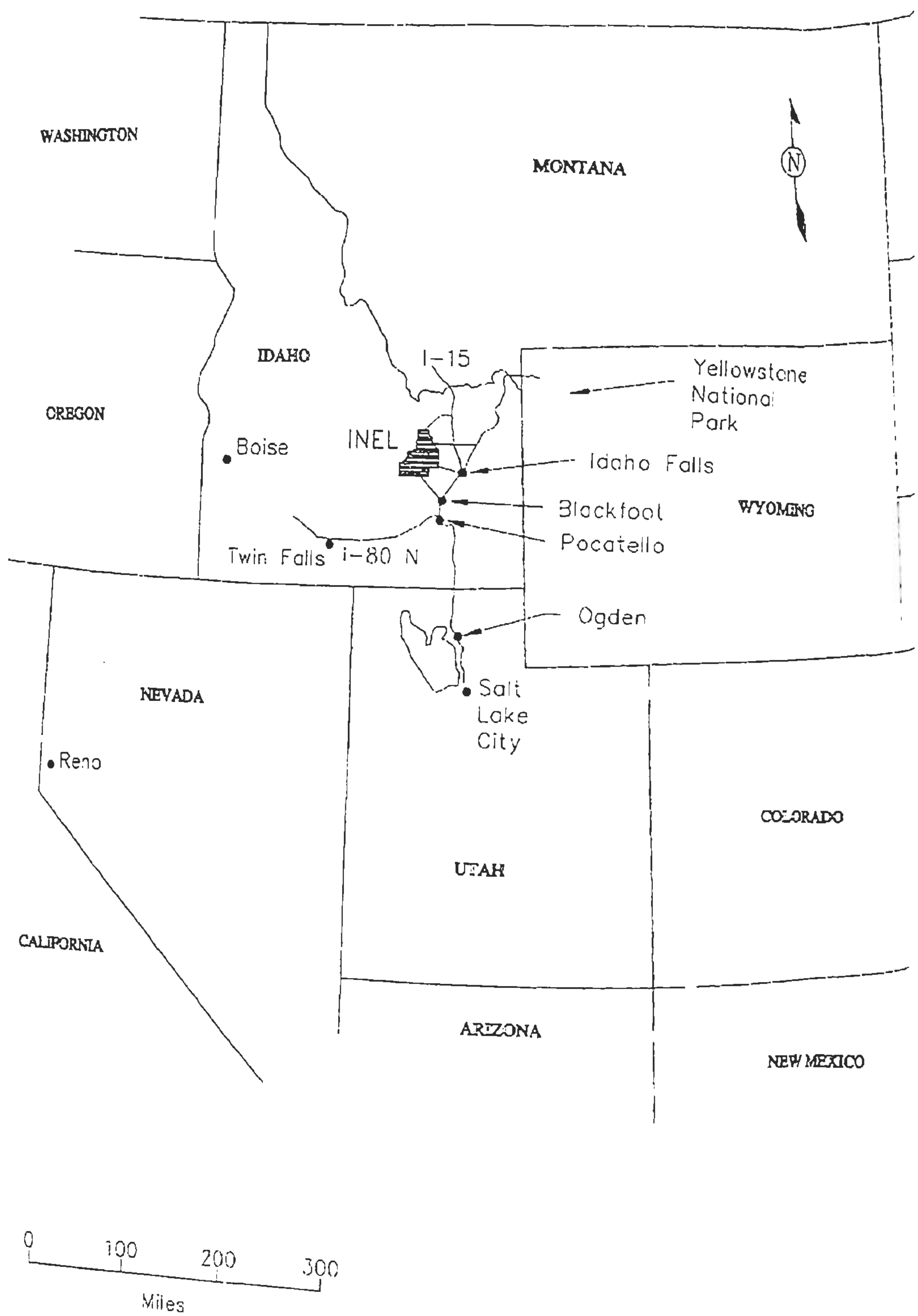


Figure 3-1. Location of INEL in relation to surrounding states.

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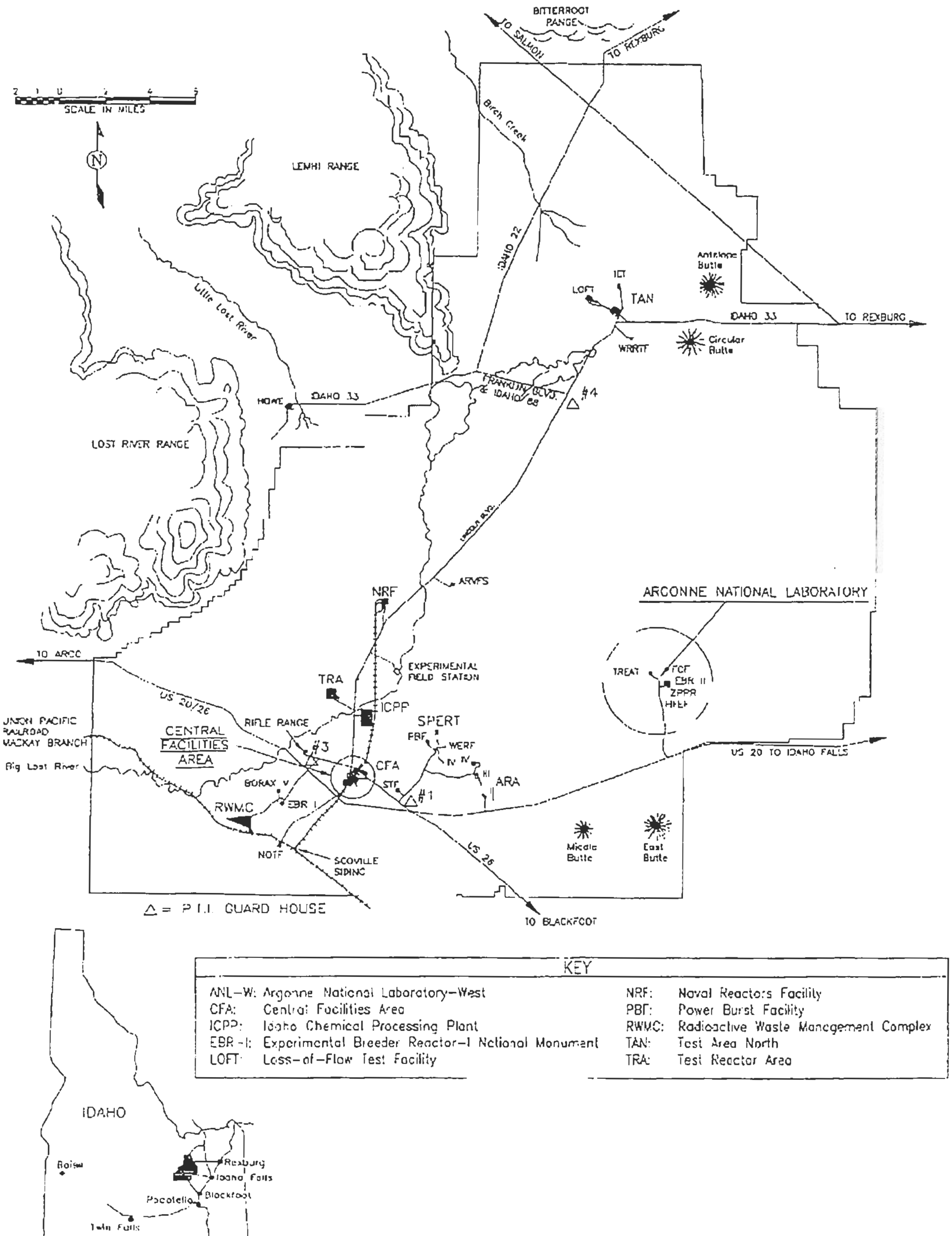


Figure 3-2. Location of primary INEL facilities and relationship to INEL site boundary.

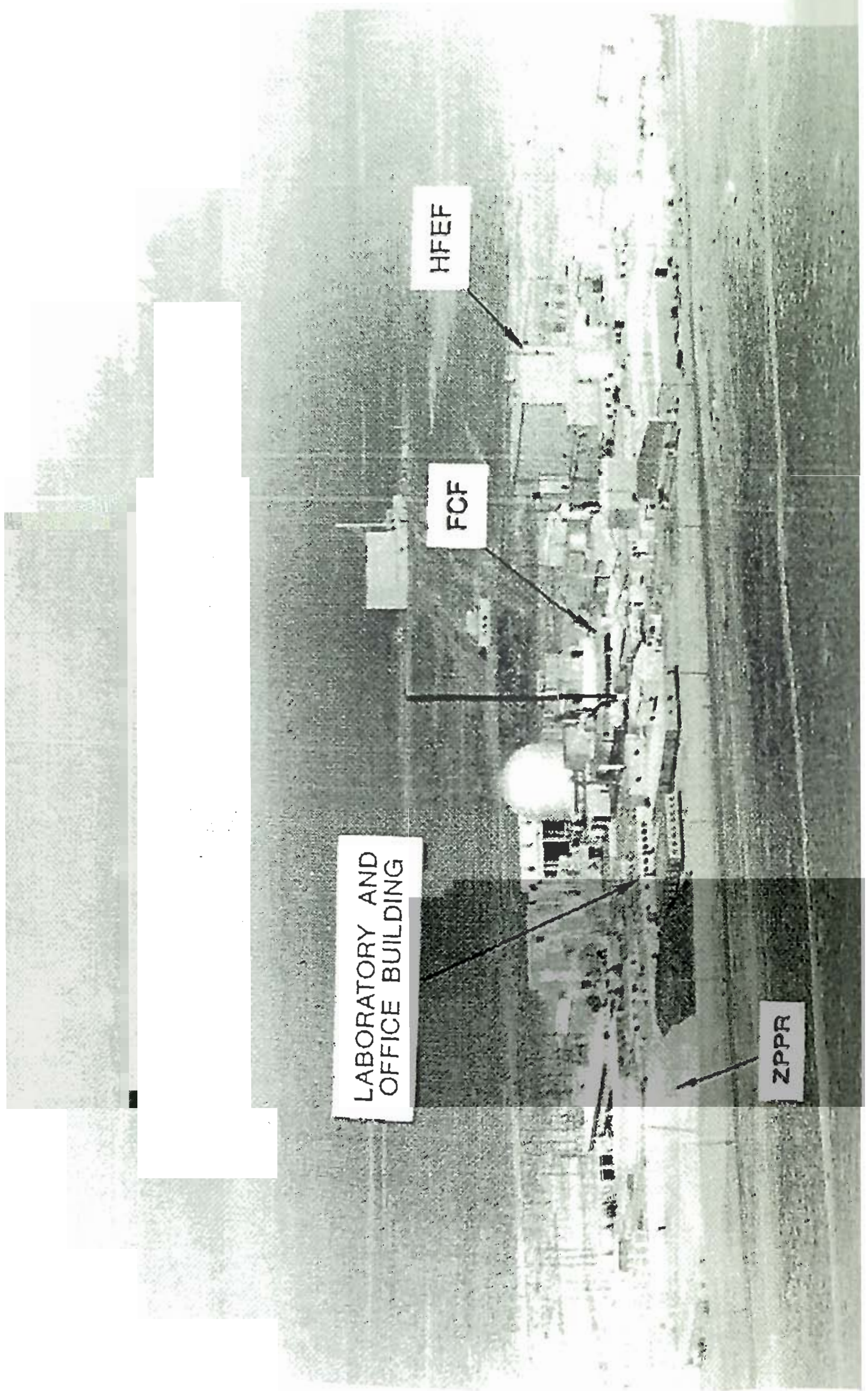


Figure 3-3. ANL-W site, looking northwest, showing the principal facilities to be used in immobilization operations.

3.2 Land Area Requirements During Operation

The facilities described for the immobilization operations are all in existence at the ANL-W site and shown in the photo (Fig. 3-3). The total ANL-W area involved extends approximately 610 m (2000 ft) east-west and 912 m (3000 ft) north-south, including parking. About half of this total area will be used for immobilization operations and their support. No additional land area will be required for the immobilization project. The existing site facilities listed previously in Tables 2-1 and 2-2 (and shown in Fig. 2-5), including shops and warehouse buildings, roads, liquid effluent treatment, and waste treatment, provide adequate support to the immobilization operations. Existing BOP systems for the FCF, HFEF, FMF, and ZPPR, such as steam instrument and plant air, and potable and process water, are adequate to support the activities involved in this immobilization project. The overall site systems also are adequate, including electricity and water, liquid effluent and waste treatment, and the site ES&H and analytical laboratories in the LOB. No changes will be required in the SEB which provides safety-grade systems for the FCF.

3.3 Land Area Requirements During Construction

No construction is expected to be required for performing the immobilization operations. The FCF was completely refurbished and upgraded in 1994 to modern standards appropriate for the immobilization project. At most, only minor modifications are expected to be required for the HFEF, FMF, and ZPPR. The immobilization project will require additional equipment not currently in place in these facilities. Existing mock-up areas are adequate for preinstallation checkout and qualification of this equipment, the principal mock-up area being located in the northeast corner of the FCF outside the FCF MAA.

4.0 Process Descriptions

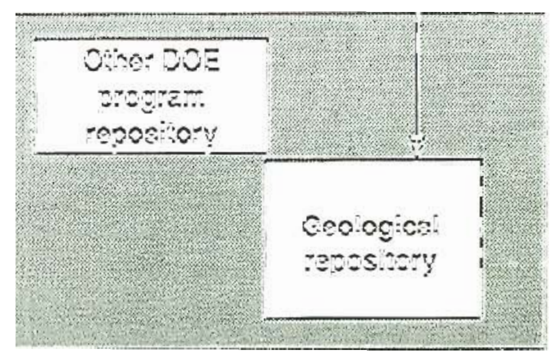
The preferred GBZ option for immobilization of surplus fissile materials described in this report and the metal alloy option (bounding case) correspond closely to the process for Electrometallurgical Treatment of DOE-owned spent fuels and the disposal of the TRU elements in these fuels. Immobilization of surplus fissile materials by either ET option employs technology that has been developed for treatment of spent nuclear fuel. The primary features of the spent fuel treatment process applicable to immobilization are (a) reduction of TRU-rich oxides; (b) electrorefining of metallic fuel to separate pure uranium from the fission products and transuranic (TRU) elements; (c) conversion of fission products to the GBZ waste form; and (d) casting of metal waste forms. The pure uranium product is stored for future use as reactor fuel or disposed in accordance with uranium disposition policy. The TRU elements and fission products can be placed either in the GBZ or a metal waste form for disposal, depending on decisions to be based on future R&D activities. The preferred disposal option is the GBZ waste form; surplus fissile material will be incorporated in the same form for disposal. A simplified version of the integrated spent fuel treatment and surplus fissile material disposition flowsheet, which produces the GBZ form, is shown as Fig. 4-1. In this integrated concept, the spent fuel treatment electrorefiner is also used for fissile material immobilization. The detailed flowsheet is shown in Fig. 4-2. Note that a separate electrorefiner is shown for fissile material immobilization in this detailed concept. The bounding case is disposal of TRU elements from spent fuel and surplus fissile materials in a metal waste form (Fig. 4-3). In the sections of this report related to environmental impacts and accident analyses, the bounding case is discussed because it results in greater potential impacts. It must be kept in mind that the preferred option is immobilization in the GBZ waste form.

4.1 Electrometallurgical Treatment of Spent Fuels

A general overview of the process to treat spent fuels is provided as background to the descriptions of the steps in the process to immobilize fissile materials. Many of the spent fuel process steps are similar to those in the immobilization process, and the processes can be carried out in much the same equipment. Details on function, feeds, products, and wastes are given where they are pertinent to the immobilization process.

4.1.1 Functions

Reduction. Two types of materials, oxides and metals, are treated by the ET process for spent fuels. Oxides (both spent fuels and plutonium oxide) are reduced to metals using a lithium reduction step. The reduction is performed at about 650°C (1200°F) in a stirred vessel containing a LiCl-rich salt. Lithium metal dissolved in the salt reduces actinide and most fission product oxides rapidly and completely. Unreduced fission products, mainly cesium and strontium, are separated from the reduction salt in a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zeolite bed described below. The spent reduction salt containing the Li_2O produced by the reduction reactions is sent to an electrowinning cell where the Li_2O is reduced electrochemically to produce lithium metal dissolved in the salt and oxygen gas, which is cleaned and vented.

Electrorefining. The metals from the reduction step are fed, along with the metallic spent fuels, to the electrorefiner, which operates at 500°C (930°F) with a LiCl-KCl electrolyte. The fuel is anodically dissolved and the bulk of the uranium is separated from TRU and fission product elements by deposition on a steel cathode. The TRU elements are allowed to accumulate in the salt if they are to be stabilized in the GBZ form, or they are collected in the cadmium cathode if they are to be disposed of in a metal form. Fission products such as cesium, strontium, and the rare earths are anodically dissolved into the molten salt phase, and accumulate mainly in the salt. Fuel cladding and the noble metal fission products either remain in the anode or are collected in a cadmium pool under the electrolyte. Fission gases, Kr, Xe, and tritium, are released into the operating cell (the cell has an argon atmosphere) and recovered by the cell gas purification system.

Zeolite Sorption. When high-fission product concentrations have accumulated in the electrolyte salt, the salt is passed through a bed of anhydrous zeolite which removes the fission product cations from the salt by ion exchange and occlusion. TRU elements can also be sorbed on the zeolite bed. The partly cleaned salt is returned to the electrorefiner. The zeolite bed is also used to remove fission products, mainly cesium and strontium, from the reduction salt.

Glass-Bonded Zeolite Fabrication. When the zeolite becomes loaded with fission products and TRU elements, it is blended with glass frit and hot pressed to make the waste form, which is then sealed in a canister. This process converts the zeolite into leach-resistant materials, which are analogous to naturally occurring minerals such as pollucite and sodalite. The pressed forms, similar to large hockey pucks, are placed in a canister that is sealed for disposal.

Metal Waste Form Fabrication. Metal products from the electrorefiner (fuel cladding and noble-metal fission products) and other metallic wastes (reactor assembly hardware and miscellaneous equipment) are melted and cast to make a metal waste form for repository disposal. If the choice is to dispose of the TRU elements in this waste form, the TRU elements collected in a cadmium cathode in the electrorefiner are also melted into this waste alloy, which is primarily a Zr-Fe alloy. The cast ingot is then sealed in a canister for disposal.

4.1.2 Feeds

The primary feeds to the treatment process are reactor assemblies containing oxide or metal nuclear fuels clad with steel or zirconium alloys. The assemblies are dismantled remotely and the clad elements are chopped and placed in steel baskets that are placed in the reduction vessel or the electrorefiner.

4.1.3 Products

The following are the products, or wastes in some cases: (a) pure uranium metal; GBZ waste form containing alkali metal, alkaline earth, and rare-earth fission produc and (c) metal waste form, which is Zr-Fe alloy with the noble metal fission products. The TRU elements are contained in either the GBZ or metal waste.

4.1.4 Utilities Required

Utilities required in the process cell are electricity and purified argon. Electrical power (440 V) is required for heating process vessels and for cell lights. The electrorefiner and lithium electrowinning cell require low voltage (~1.3 V) and high amperage (~1000 A) power. There is a gas purification system that removes oxygen, water, and heat from the argon atmosphere in the process cell. Cooling water and instrument air are required for equipment outside the process cell.

4.1.5 Chemicals Required

The main process fluids, salts, cadmium, and lithium, are recycled in the fuel treatment process, but small amounts must be fed as makeup for process losses. The chief chemicals required are: anhydrous Zeolite A, glass frit, steel cans for hot pressin and steel waste containers.

4.1.6 Special Requirements

Other than the safety grade systems required for occupied facilities handling radioactive and fissile materials, only normal utilities and services are required, such heating, ventilation, water sewer, electrical, and lighting. The required safety grade emergency power is supplied by two independent diesel generators housed in a safety grade structure. Emergency exhaust for the process cell is also provided.

4.1.7 Process Waste

The electrometallugical processes are dry processes that produce contaminated water only from decontamination of equipment, chemical analysis, and water remove by the cell gas purification system. High-level wastes are the product waste forms described above. Low-level wastes are those generally associated with radioactive processes. Fission gases, Kr and Xe, are separated from the cell atmosphere as nearly pure gases and contained in low pressure gas cylinders. Tritium contained in the low volumes of water removed from the cell atmosphere is stored in tanks.

4.2 Electrometallurgical Treatment of Fissile Materials—Reduction

4.2.1 Function

This process step reduces oxide residues rich in plutonium and minor actinides to actinide metals. It operates in the same manner as the reduction step described in

4.3.2 Feeds

Fissile materials as metals from weapons or from the reduction step are fed to the electrorefiner to produce actinide chlorides. Waste salt from the spent fuel process, containing fission products and TRU chlorides, is a makeup feed to the immobilizatio process step.

4.3.3 Products

Actinide chlorides, CsCl, and other fission products dissolved in molten salts are produced.

4.3.4 Utilities Required

Electrical power to heat the process vessel, and purified argon cover gas are required. Low-voltage, high-current power is needed to drive the electrorefining step.

4.3.5 Chemicals Required

Chlorinating agents, such as $CdCl_2$ or $FeCl_2$, are required. Makeup salt from the spent fuel treatment process is required to replace the salt contained in the GBZ waste form.

4.3.6 Special Requirements

There are no special requirements for this process step.

4.3.7 Wastes Generated

The metal baskets used to introduce the metal feed will eventually become waste which will be immobilized in the process.

4.4 Electrometallurgical Treatment of Fissile Materials—Zeolite Sorption

4.4.1 Function

The alkali metal, alkaline earth, and rare earth fission products are removed from the electrorefining and reduction salts. The sources of these fission products are the spent fuels, which are being treated and the cesium from the Hanford capsules. Fission product cations are sorbed on the zeolite by ion exchange. Fission product anions such as iodine are sorbed into the zeolite molecule by occlusion. The TRU elements immobilized in the ceramic waste form are also sorbed by ion exchange.

4.4.2 Feeds

Molten salt solutions containing fission product and TRU element chlorides are fed to this step from the electrorefiner. Chloride residues are fed to this step, and anhydrous zeolites become the absorption medium.

4.4.3 Products

Zeolite powder saturated with fission products, salt, and TRU elements.

4.4.4 Utilities Required

Electrical power to heat the process vessels and transfer lines and for mixing the material.

4.4.5 Chemicals Required

Anhydrous Zeolite A, lithium or potassium form, is required.

4.4.6 Special Requirements

There are no special requirements for this process step.

4.4.7 Wastes Generated

No direct process wastes are produced by this step.

4.5 Electrometallurgical Treatment of Fissile Materials—Ceramic Waste Form Fabrication

4.5.1 Function

The loaded zeolite powder is blended with a suitable glass frit, charged into steel containers and hot pressed to produce the ceramic waste form. The zeolite is converted to stable, leach-resistant compounds that are similar to natural minerals, such as sodalite and pollucite. The pressed waste forms (pucks) are loaded into waste canisters and seal welded for repository disposal. These canisters are placed in interim storage.

4.5.2 Feeds

Loaded zeolite powder, glass frit, and steel vessels are fed to this step.

4.5.3 Products

The GBZ waste forms are produced in steel cans.

4.5.4 Utilities Required

Electrical power to heat the waste during pressing. Hydraulic pressure for the hc press (or pneumatic pressure). Electrical power for welding the cans and canisters.

4.5.5 Chemicals Required

Glass frits.

4.5.6 Special Requirements

There are no special requirements for this process step.

4.5.7 Wastes Generated

Aqueous waste from decontamination of the waste canisters before interim storag

5.0 Resource Needs

Only those resources required for immobilization in GBZ form over and above those required for spent fuel treatment are described, because existing facilities, equipment, and personnel are already committed to the fuel treatment options. The ANL-W facilities which are already equipped for electrometallurgical treatment of spent nuclear fuel are described, along with the additions needed to incorporate this plutonium disposition option as a closely related activity using the same facilities and equipment.

5.1 Materials/Resources Consumed during Operation

5.1.1 Utilities Consumed

The only additional utilities required in this option are electricity for new process furnaces and an increase in water consumption due to the increase in the number of employees. The utility requirements are summarized in Table 5-1. The water requirement, based on historical data for site operations, is a conservative estimate because of the shutdown of some reactor facilities.

Table. 5-1. Additional site utilities consumed during immobilization operations.

Utilities	Average annual consumption	Peak demand
Electricity	2.4×10^6 kW-h	8 kW
Liquid Fuel	0	N/A
Natural Gas	0	N/A
Raw Water (Dry Site)	610,000 L (160,000 gal.)	N/A
Raw Water (Wet Site)	610,000 L (160,000 gal.)	N/A

5.1.2 Water Balance

No process water is required for this option. A modest increase in water is required for a nominal 20% increase in the site population. A simplified water balance diagram is shown in Fig. 5-1.

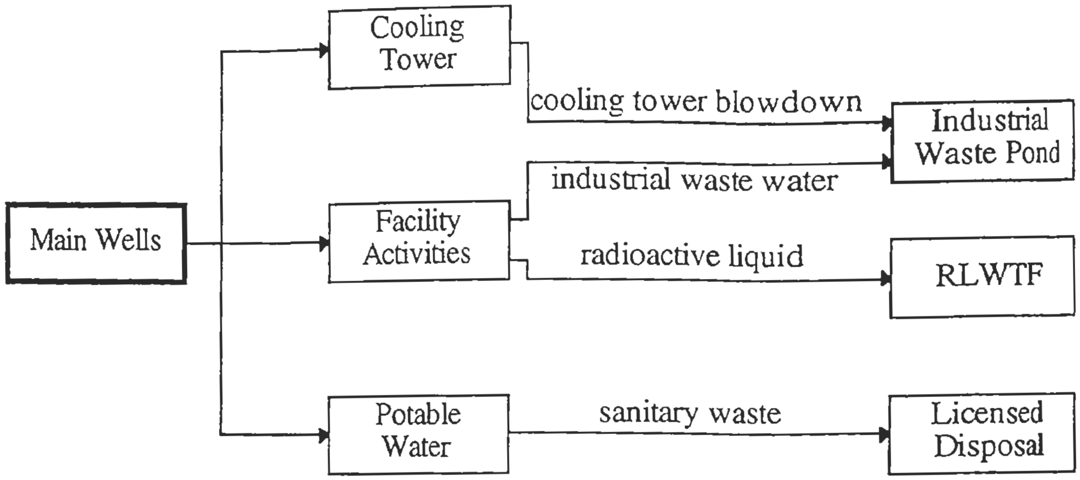

Figure 5-1. Simplified water balance diagram for ANL-W.

5.1.3 Chemicals Consumed

This option requires a minimal amount of chemicals over and above those used in the spent fuel treatment activities. Some additional process salt is required for the additional material processed. Additional zeolite and glass are required to stabilize the incremental cesium chloride and plutonium chloride with the fission products from the spent fuel treatment in the waste stream of the electrorefiner. The chemical requirements for this option are summarized in Table 5-2.

Table 5-2. Annual chemicals consumed during operation.

Solid chemicals	Quantity (kg) (lb)
Potassium chloride/lithium chloride salt	34,000 (74,800)
Zeolite, glass	77,000 (169,400)
Liquid chemicals	0
Gaseous chemicals	0

5.1.4 Radiological Materials Required

Annual requirements for radiological materials consist of the five metric tons of plutonium for disposition and 64 kg (140 lb) of radioactive cesium that is immobilized within the waste package. These requirements are summarized in Table 5-3.

Table 5-3. Radiological materials consumed annually during operations.

Material	Form	Quantity kg (lb)
Plutonium	Metal and oxide	5,000 (11,000)
Cesium	Cesium chloride salt in steel capsules	64 (140)

5.2 Materials/Resources Consumed during Construction

No construction is required for this option. The additional process equipment will be shipped in from offsite and installed in existing space. The time required to install the equipment is less than six months. Installation would occur during shutdown for scheduled maintenance and inventory clean-out for safeguards accountability. For this evaluation, two months operation of the site and the facilities are charged to the plutonium disposition project in lieu of any actual construction. The impact of these activities is summarized in Table 5-4.

Table 5-4. Materials/resources consumed during construction.

Materials/resources	Total consumption	Peak demand[1]
Utilities		
Electricity	5.3×10^6 kW-h	3,000 kW
Water	1.5×10^7 L (4×10^6 gal)	79,000 L (20,800 gal)
Solids	N/A	N/A
Liquids		
Fuel oil	5.7×10^5 L (1.5×10^5 gal)	N/A

[1] Peak demand is the maximum rate expected during any hour.

6.0 Employment Needs

This immobilization option uses primarily employees engaged in ongoing DOE spent fuel treatment activities. Additional employees are required to take care of operation of the additional equipment and to satisfy the additional security and safeguards requirements. The basis for this report section is that classified characteristics of weapons materials are eliminated at a separate secure site and only unclassified materials are handled at the ANL-W site such that a minimum number of additional security and technical support personnel are required for immobilization operations (Table 6-1).

Table 6-1. Employment during operations.

Labor category	Number of employees
Officials and managers	5
Professionals	15
Technicians	14
Office and clerical	5
Operators/line supervision	37
Safeguards and security	7
Total Employees	83

6.1 Badged Employees at Risk of Radiological Exposure

The additional employment required for this option adds minimally to the total number of badged employees at risk of radiological exposure. As summarized in Table 6-2, 73 of the 83 additional employees would be badged for potential radiological exposure. In addition, a small number of badged visitors may enter the radiological area, but this is envisioned to be on a nonroutine basis. The average exposure at ANL-W during FY 1994 was approximately 400 μSv (40 mrem) per badged individual. The highest individual exposure was 8.4 mSv (0.835 rem). These personnel exposures are typical of expected exposures for plutonium disposition personnel.

Table 6-2. Additional employees at risk of radiological exposure.

Labor category	Number at risk
Operators/line supervision	37
Technicians	14
Professionals/managers	15
Safeguards and security	7
Total	73

6.2 Employment Needs during Construction

No additional construction employees are required for this option which uses existing facilities. However, as a conservative assumption, six months of total site operation is charged to "construction" for this disposition option. The site employment during this period is summarized in Table 6-3. Employment during plutonium immobilization operations is shown previously in Table 6-1.

Table 6-3. Employment needs during suspended operations charged to construction.

Labor category	Number of employees
Officials and managers	30
Professionals	90
Technicians	79
Office and clerical	30
Operators/line supervision	222
Safeguards and security	42
Total	493

The radiological emissions given in Table 7-2 are the release values scaled from the Environmental Assessment for FCF. Although the releases attributed to plutonium disposition operations will be considerably less, the values shown here can be used to bound probably releases.

Table 7-2. Annual radiological emissions during operation.

Radiological isotope	Release rate GBq/yr (Ci/yr)
Alpha radiation (including TRU)	$<1 \times 10^{-2}$ ($<3 \times 10^{-4}$)
Beta and beta-gamma radiation (including cesium)	$<7 \times 10^{-3}$ ($<2 \times 10^{-4}$)

7.1.2 Solid and Liquid Wastes

The plutonium disposition operations are performed as part of the spent fuel treatment operations. Adding plutonium operations does not significantly increase solid or liquid wastes. All liquid radioactive wastes, e.g., from washing operations, are dried and solidified. A block diagram for ANL-W waste operations is shown in Fig. 7-1.

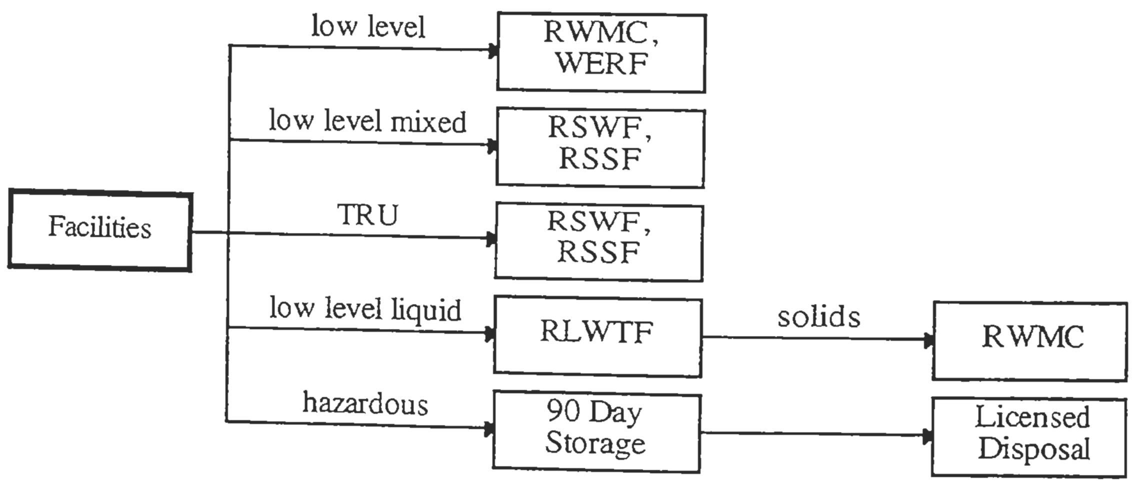

Figure 7-1. Block diagram of ANL-W waste operations.

7.1.2.1 High-Level Wastes. The plutonium disposition operations are performed as part of the spent fuel treatment operations. The plutonium is to be combined with the spent fuel high-level waste, and processed into a GBZ waste form which is made from hot-pressed zeolite and glass frit. Radioactive cesium will field.

In processing the additional plutonium, the mass of the high-level waste increases by the amount of plutonium, cesium, and ceramic binder added. The amount of high-level waste attributed to plutonium disposition operations is provided in Table 7-3.

Table 7-3. **Annual waste volumes from disposition operation.**

Category	Generated	Quantities	Post	Treated
	Solid m^3 (yd^3)	Liquid L (gal)	Solid m^3 (yd^3)	Liquid L (gal)
Spent fuel	0	0	0	0
High-level waste (plutonium disposition product)	0	0	37 (49)	0
Transuranic waste (TRU)	6 (8)	0	6 (8)	0
Low-level waste (LLW)	55 (72)	0	55 (72)	0
Mixed transuranic waste	<0.76 (<1)	0	<0.76 (<1)	0
Mixed low-level waste	<0.76 (<1)	0	<0.76 (<1)	0
Hazardous waste	0.76 (1)	0	<0.76 (<1)	0
Nonhazardous (sanitary) wastes	1,500 (2,000)	2.7×10^6 (720,000)	1,500 (2,000)	2.7×10^6 (7.2×10^5)
Nonhazardous (other) wastes	540 (700)	1.1×10^6 (300,000)	0	1.1×10^6 (3.0×10^5)
Recyclable	0.76 (<1)	<380 (<100)	<0.76 (<1)	<380 (<100)

7.1.2.2 Transuranic Wastes. The amount of additional transuranic waste produced beyond the baseline spent fuel treatment program is determined essentially the same way as the data provided in Table 7-1. It is assumed to be 20% of the baseline value since the additional heavy metal throughput for plutonium operations is less than 20% of the total heavy metal input for both the spent fuel treatment and plutonium disposition programs. Although the spent fuel processed annually does not contain as much transuranics as the amount of plutonium to be disposed, the remote, shielded operations are already contaminated by the spent fuel operations. The baseline values are also derived from data in the FCF Environmental Assessment. The transuranic waste value is given in Table 7-3.

7.1.2.3 Low-Level Wastes. The amount of additional low-level waste produced beyond the baseline spent fuel treatment program is also assumed to be 20% of the baseline value for the combined programs. The low-level waste value is given in Table 7-3.

7.1.2.4 Mixed Transuranic Wastes. The amount of hazardous materials used in both the large-scale spent fuel treatment and plutonium disposition programs are minimized, and therefore the amount of mixed wastes generated are small. The mixed transuranic waste value is given in Table 7-3.

7.1.2.5 Mixed Low-Level Wastes. The amount of hazardous materials used in both the large-scale spent fuel treatment and plutonium disposition programs are minimized, therefore the amount of mixed wastes generated are small. The mixed low-level waste value is given in Table 7-3.

7.1.2.6 Hazardous Wastes. The amount of hazardous materials used in both the large-scale spent fuel treatment and plutonium disposition programs are minimized, therefore the amount of hazardous wastes generated are small. The hazardous waste value is given in Table 7–3.

7.1.2.7 Nonhazardous (Sanitary) Wastes. The amount of solid and liquid sanitary wastes, as shown in Table 7-3, is determined by taking 20% of the annual generation rate for the site. The water usage value for an individual is the same as used for the FCF Environmental Assessment.

7.1.2.8 Nonhazardous (Other) Wastes. The operation of the FCF requires recycled water for cooling systems. Makeup water is needed to account for evaporation loss in the cooling tower. For the entire baseline program, 5.7×10^6 L (1.5×10^6 gal) is needed per year. The plutonium disposition program accounts for 20% of the nonhazardous solid and liquid wastes, as shown in Table 7-3.

7.2 Wastes and Emissions during Construction

This plutonium disposition option makes use of existing facilities at ANL-W. The facilities are already modified for treating spent fuel from EBR-II and for the initial phases of the spent fuel treatment program using an electrometallurgical technique. Any other expected modifications are part of the expanded spent fuel treatment operations. Extensive modifications will not be required for plutonium disposition work.

The emission values attributed to construction in Tables 7-4 and 7-5 are those released from the facilities during the time period when new equipment for plutonium disposition operations is being installed. However, as a conservative assumption, six months of facility emissions are attributed to plutonium disposition modifications.

Table 7-4. **Emissions during the peak construction year.**

Criteria pollutants	Quantity tonnes (tons)
Sulfur dioxide	0.05 (0.06)
Nitrogen oxide	0.46 (0.51)
Volatile organic compounds	0.11 (0.12)
Carbon monoxide	0.11 (0.12)
Particulate matter	0.04 (0.04)
Lead	0

7.2.1 Emissions

Since additional facility modifications and construction are not required, emissions beyond those from the spent fuel treatment program are not significant.

7.2.2 Solid and Liquid Wastes

Since additional facility modifications or construction are not required, solid and liquid wastes beyond those from the spent fuel treatment program are not produced.

7.2.2.1 Radioactive Wastes. Since additional facility modifications and construction are not required, radioactive wastes beyond those from the spent fuel treatment program are not generated.

7.2.2.2 Hazardous Wastes. Since additional facility modifications and construction are not required and a minimum amount of hazardous material is used in the combined programs, significant quantities of hazardous wastes are not produced.

7.2.2.3 Nonhazardous Wastes. Additional facility modifications and construction are not required, however, as a conservative assumption, six months of nonhazardous solid wastes are attributed to plutonium disposition modifications.

Similarly, nonhazardous liquid wastes, sanitary liquid wastes, and other nonhazardous liquid wastes are attributed to plutonium disposition modifications.

Table 7-5. Total wastes generated during construction.

Waste category	Quantity
Hazardous solids	0 m^3 (0 yd^3)
Hazardous liquids	0 L (0 gal)
Nonhazardous solids	
Concrete	0 m^3 (0 yd^3)
Steel	0 tonnes (0 tons)
Sanitary	5,734 m^3 (7,500 yd^3)
Other	<1 m^3 (<1 yd^3)
Nonhazardous liquids	
Sanitary	2,780,000 L (735,000 gals)
Other	2,840,000 L (750,000 gals)

8.0 Design Process for Accident Mitigation

A principal requirement for any accident assessment is the determination of the type, quantity, and location of materials at risk, i.e., those materials whose release to the environment must be calculated and the consequences of which assessed. Since the FCF is used for the treatment of a variety of DOE reactor fuels, many process uncertainties exist; these include the types and quantities of materials at risk within the argon cell. As a result, the safety analyses are based on conservative assumptions that are expected to bound any campaign that may be conducted during the DOE spent fuel treatment program. For comparison, the materials-at-risk considered for the FCF Safety Analysis Report, based on a program of treatment of EBR-II fuel, are also described in Table 8-1. This provides a basis for extrapolation of the accident consequences for the proposed surplus plutonium immobilization program since the electrometallurgical processes are essentially the same and the bounding accidents evolve in the same way. The processes to produce metal immobilization forms (bounding case) are considered in these analyses, because they result in the largest accident impacts attributable to immobilization operations.

The hazardous materials inventory includes materials "at risk" of being dispersed from the FCF argon cell during the process of introducing surplus plutonium into the waste streams from the treatment of DOE spent fuel and casting the product into a suitable storage form. This material is open to the argon cell atmosphere at some time during processing. Also included are materials stored in "defense-in-depth" containers awaiting processing or removal from the cell. This material is not considered "at risk" for any design basis event but could be "at risk" in a beyond-design-basis event. Finally, some of the materials are possibly in a pyrophoric state by virtue of their temperature and surface-to-volume ratio; these are noted in the inventory because they provide the potential energy source for dispersion of hazardous materials.

Energy sources for dispersion of hazardous materials are severely limited by the nature of the electrometallurgical process. There are no pressurized vessels or piping systems required; the process vessels assure confinement of metal being processed and the only pressurized gas is argon in small purge lines. The argon cell atmosphere is inert. The small batch sizes used in the process limit the stored thermal energy in the process materials and no highly combustible materials are required for the process.

The primary energy source for dispersion of hazardous materials is combustion of pyrophoric metals caused by a breach of the cell boundary and introduction of air into the cell. The primary safety system for the facility is a safety class exhaust system designed to control such an event by ensuring that the cell atmosphere remains below atmospheric pressure so that combustion products are HEPA filtered before being released up the exhaust stack.

Table 8-1. Bounding inventory of hazardous materials for the FCF argon cell safety analysis.

Hazardous and radioactive materials description	Material classification	FCF original safety analysis	Material associated with DOE spent fuel treatment	Additional material associated with Pu immobilization
Clad fuel	Not at risk	Not quantified	0	0
Chopped spent fuel (various compositions)	At risk pyrophoric	14 kg (31 lb) U 6 kg (13.2 lb) Pu+TRU	0	0
Chopped spent fuel (various compositions)	Not at risk	Not quantified	0	0
^{85}Kr	At risk	67 TBq (1810 Ci)	7.4×10^3 TBq (2×10^5 Ci)	0
Metallic Na	At risk pyrophoric	Small	0	0
U (solid and liquid Cd cathode products)	At risk pyrophoric	19 kg (41.8 lb)	1 kg (2.2 lb)	0
U in storage	Not at risk	Not quantified	10 kg (22 lb)	0
TRU (including Pu) from spent fuel treatment	At risk pyrophoric	6kg (13.2 lb)	2 kg (4.4 lb)	0
TRU (including Pu) in storage	Not at risk	Not quantified	10 kg (22 lb)	0
Salt in process	Not at risk			0
Salt in storage	Not at risk	Not quantified		0
Liquid Cd in process	Not at risk			0
Misc metal waste including cladding hulls	No risk	Not quantified	540 kg (1,188 lb)	0
Metal ingots	Not at risk	0	4 kg (8.8 lb) Pu+TRU 2 kg (4.4 lb) U 358 kg (787.6 lbs Misc metal waste	36 kg Pu (79.2 lb)
Loaded zeolite input from spent fuel treatment (contains ^{137}Cs and ^{90}Sr)	At risk	0	740 TBq (20 kCi) ^{137}Cs 520 TBq (14 kCi) ^{90}Sr	0
CsCl in process (from Hanford capsules)	At risk	0	0	740 TBq (20 kCi) ^{137}Cs
CsCl (1 day inventory)	Not at risk	0	0	740 TBq (20 kCi) ^{137}Cs
Loaded zeolite output	Not at risk	0	740 TBq (20 kCi) ^{137}Cs 520 TBq (14 kCi) ^{90}Sr	740 TBq (20 kCi) ^{137}Cs

Immobilization Form (1 day inventory awaiting transfer to ZPPR)	Not at risk	0	4 kg (8.8 lb) Pu+TRU 2 kg (4.4 lb) U 1500 TBq (40 kCi) ^{137}Cs 1040 TBq (28 kCi) ^{90}Sr	36 kg (79.2 lb) Pu 1500 TBq (40 kCi) ^{137}Cs

In addition, the safety systems and programs for the facility involve multiple confinement barriers; passive, filtered, pressure relief for the argon cell; controlled pressure gradients to minimize the spread of contamination; redundant criticality control procedures; a combustibles control program backed by fire suppression systems, adherence to a "no unfiltered release" criterion, and double HEPA filtration of "suspect" gases.

8.1 Operational and Design Basis, and Beyond-Design-Basis Bounding Accidents

8.1.1 Operational and Design-Basis Accidents

The criteria used to select accidents for this assessment are the following: (1) that the event could result in a release from the facility of radioactive material and/or chemical reagents over and above that expected from spent fuel operations, (2) that the event bounds all similar events, and (3) that the accident is associated with the additional risk of the surplus plutonium immobilization program being included in the ongoing DOE spent fuel treatment program. These criteria were applied to the design basis accidents analyzed for the FCF SAR and resulted in the identification of the following design basis accidents (DBAs):

1. Argon cell overpressurization with no breach
2. Material handling and storage accidents
3. Breach of argon-cell confinement

The first event might lead to an activity release through the safety exhaust system (SES), which is activated when the argon cell pressure increases to a predetermined level. The second event recognizes that mishaps during the handling of confined hazardous materials (e.g., plutonium) might result in damage to the confinement and a release to the surroundings of a fraction of such materials. The third event could result in drawing air into the argon cell through the breach. If the resulting air content in the cell is high enough, rapid oxidation of exposed, hot metals could result in a fire, a cell pressure increase, and a release of hazardous materials through the SES.

Each of the above DBAs might be initiated in different ways. For example, argon cell overpressurization with no breach could result from a loss of the cell cooling system or malfunction of the argon supply system. Similarly, some initiating events may have multiple effects. For example, a design-basis earthquake might cause the simultaneous failure of utilities, the argon cell cooling system, and the argon-cell confinement.

Each event is classified according to its likelihood of occurrence using the following categories approved in the FCF SAR:

Anticipated: Incidents that may be expected to occur once or more during the lifetime of the facility.

Unlikely: Accidents that are not expected but may occur sometime during the life cycle of the facility.

Extremely unlikely: Accidents that will probably not occur during the life cycle of the facility. This category includes design basis accidents.

For each accident category, the FCF SAR adopted radiological dose guidelines for assessing acceptability of the accident consequences, Table 8.2. The consequences of the FCF SAR accident analyses were expressed in percentages of the guideline values. The consequences of accidents associated with DOE spent fuel treatment with surplus plutonium immobilization can be estimated by comparison to similar accidents analyzed for the FCF facility. The comparison involves the quantities of hazardous materials involved, the available dispersion energy, and the accident mitigation features available. Table 8.3 summarizes the DBAs discussed in the remainder of this section.

8.1.1.1 Loss of Off-Site Power. Preferred electrical power is a subset of normal power. The loss of normal power results in a loss of both preferred and normal power loads. Preferred power is backed up by the diesel-generator (DG) emergency-power system. Each of the redundant DGs supplies power to both safety-class, 1E, and non-1E emergency loads.

Table 8-2. Radiological dose acceptance criteria approved for the FCF SAR. These criteria are used for judging the acceptability of design-basis accidents.

		Committed effective dose equivalent guideline, mSv or 10^2 mrem	
DBA classification	Frequency (events/yr)	Public	Worker
Anticipated	0.01–1	0.1	10
Unlikely	0.001–0.01	1	50
Extremely unlikely	0.0001–0.000001	50	200

8.1.1.2 Plutonium Container Drop. The path of a sealed plutonium container is normally from the transfer cask in the tunnel beneath the air cell, through a bagged-transfer device that maintains an atmosphere seal between the air cell and the cask, to the air cell, and eventually into the argon cell for processing. During the handling of the plutonium container within the air cell, some handling mishaps could occur in which the can loses its integrity, exposes its contents and releases some fraction of the plutonium. The "unlikely" categorization for this event is due to the type-testing performed to show the container will survive a drop.

Since the drop is assumed to happen in the air cell, any release to the atmosphere will occur through the air cell exhaust system. The air cell exhaust includes two stages of HEPA-filters in series with a combined efficiency for particulate trapping of 99.99% (i.e., particulate effluent reduction factor = 1×10^{-4}). The release is assumed to be a "puff" rather than a continuous release.

In addition to the reduction of the release fraction that is available from the two series stages of HEPA filters, i.e., 0.0001, further reductions for this accident are affected by (a) plateout or fallout of material within the facility before release to the atmosphere (assigned a factor of 0.5), and (b) the fact that only a small fraction of the material will become airborne in the immediate area as a result of an accidental drop with resulting breach of the container. The latter factor has not yet been evaluated and will depend upon the physical characteristics of the plutonium material and must include consideration of the potential for a resulting fire in the spilled contents of the container. Based on the analysis in the FCF FSAR, the release fraction for this accident, including the reduction by the HEPA filters, is estimated to be $f \times 0.00005$, where f is the fraction of the material that becomes airborne in the immediate area of the drop accident.

The following mitigating systems will be available during and following an accident: the emergency power system, the air cell confinement system including the building and air cell exhaust systems and their associated HEPA filters, the stack, and the mitigating effects of the site location.

8.1.1.3 Design-Basis Earthquake and Pyrophoric Metal Fire. The primary concern is the combustion of the heavy actinide elements in pyrophoric, metallic form within the cell and the resultant potential for releases of radioactive and/or toxic materials. Because the fuel processing will be conducted in an inert argon atmosphere, fire cannot occur unless sufficient oxygen is introduced into the argon cell. The only source of oxygen in such quantities is from air entering the cell through one or more breaches of its boundary. Therefore, accident scenarios consider possible breach points and rates at which air could enter the cell.

The walls, ceiling, and floor of the argon cell are constructed from reinforced concrete with thicknesses ranging from 1.2 to 1.5 m (4 to 5 ft). It also has a gas-tight steel lining. The cooling system cubicles, although not lined, have three thick reinforced-concrete walls and one sealed steel wall. However various small purge lines, argon cooling system piping, and some additional argon cell purification system piping can be assumed to break allowing air to enter the cell. The assumed breach area is less than one square foot.

The FCF FSAR describes the calculations of the evolution of this event. The release fractions for combustion used in those calculations are given in Table 8.4.

Table 8-4. Source-reduction factors used for releases from fires in DBA 8.1.1.3.

Nuclide	Fire release fraction	Plateout fraction	HEPA filters (2 stages)	F(Product)
Pu	0.0005	0.5	0.0001	2.5×10^{-4}
Cs	0.35	0.5	0.0001	0.175
Other solid fission products	0.0005	0.5	0.0001	2.5×10^{-4}

The following mitigating systems will be available during and following this accident: the 1E emergency power system, the argon-cell confinement system, the defense-in-depth containers in the argon cell, the safety exhaust system with two stages of in-series HEPA filtration, and the mitigating effects of the site location.

8.1.2 Beyond-Design-Basis Accidents

The FCF FSAR does not discuss beyond design basis accidents so that the events discussed in this section have no direct comparison. However, a preliminary analysis was given in the FCF Environmental Assessment. The events chosen for discussion are an event which defeats the safety class mitigating system and a criticality event which introduces a beyond design basis energy source to the facility. The likelihood-of-occurrence of these events are such that they would be judged to be outside the normal range for DBAs, i.e., typically less than 1×10^{-6} per year.

8.1.2.1 Beyond-Design-Basis Earthquake and Cell Metal Fire. This accident is as described in Section 8.1.1.3, except that it assumes failure of safety-class mitigation equipment. The HEPA filters in the SES, although capable of surviving the DBE, are assumed to be damaged and to have a reduced attenuating capability for this beyond-DBE event. The energy source is as described previously, i.e., the combustion energy of argon cell pyrophoric material at risk. No analysis of this event has been conducted in the FCF FSAR, but the consequences can be estimated by assuming failure of the HEPA filter mitigating factor in the DBE metal fire accident of Section 8.1.1.3. The release fractions are therefore estimated as 0.175 for Cs and 0.00025 for plutonium and other solid fission products. This accident would be predicted to result in an effective whole body equivalent dose at the site boundary that is 30% of the 10CFR100 siting guideline, 250 mSv (25 rem). Only the mitigating effect of the site location will be available during and following this accident.

8.1.2.2 Argon Cell Criticality Event. In the preliminary safety analysis for FCF, an assessment of the consequences of a "reference" criticality accident was discussed. The total yield was assumed to be 10^{18} fissions, a commonly accepted value for super-prompt-critical assemblies of unmoderated plutonium. The accident modeling assumed that all the energy goes into heating and vaporizing the U-Pu-Zr fuel in a pin casting crucible, with immediate uniform transfer of heat and mixing of aerosol with the cell atmosphere. The results of this assessment showed a modest cell overpressure 6.2 kPa (<0.9 psi) and a whole-body dose equivalent at the site boundary, with credit for HEPA filtration, of 250 mSv (10 mrem), only 0.04% of 10CFR100 siting dose criteria.

For the conditions of the DOE spent fuel treatment program with surplus plutonium immobilization, a similar bounding criticality event could be postulated with the single change of assuming that the fission energy goes into the 18 kg (40 lb) charge of pure Pu being added to the metal ingot. The accident will proceed as before and the amount of Pu involved would be similar because batch sizes are controlled to prevent criticality. The consequence would be about 0.05% of the dose guidelines for workers in "extremely unlikely" events.

For the criticality described in FCF preliminary analysis, 30% of a 40 kg (88 lb) heavy metal batch (21% Pu), or 12 kg (26.4 lb) of heavy metal, was determined to be vaporized due to the 32.3 MW-s fission energy. The vaporized fuel was assumed to be uniformly mixed in the cell, and 6.3 % was calculated to be released from the cell due to the resulting expansion of its atmosphere. The total release fraction for plutonium, including the two series stages of cell exhaust HEPA filters, was estimated as $0.3 \times 0.063 \times 0.0001$, or 1.9×10^{-6}. All of the fission products, except for iodine and the noble gases, were assumed to be uniformly mixed in the cell atmosphere, with the HEPA filters being effective in attenuating the release, and therefore to have a release fraction of 0.063×0.0001, or 6.3×10^{-6}. For iodine, which is a consideration here because of the high power and short radioactive decay time, and for the noble gases, the release fraction was assumed to be 0.063 due solely to uniform mixing and expanding of the cell atmosphere.

The predicted dose for this criticality event was almost entirely due to the vaporized plutonium, which was 21% of the 12 kg (26.4 lb) total vaporized heavy metal, or 2.5 kg (5.5 lb). For the conditions of the DOE spent fuel treatment with surplus plutonium immobilization, a similar bounding criticality event could be postulated with the single change of assuming that the fission energy goes into an 18 kg (39.6 lb) charge of pure plutonium added to the metal ingot. Under these conditions, almost all of the charge would be vaporized. Under the preliminary analysis assumptions, the fraction of cell atmosphere released will tend to increase in accordance with the increase in heavy metal vaporized. Likewise, the dose will be increased over the dose from preliminary analysis in accordance with the increase in the amount of plutonium vaporized. Therefore the effective whole body equivalent dose received by an individual at the site boundary can be estimated from the following:

$$\text{Dose} = 0.1\ \text{mSv (10 mrem)} \times [(0.063 \times 18/12)/0.063] \times (18/2.5).$$

The estimated dose for the DOE spent fuel treatment criticality event is therefore an effective whole body equivalent of 1.1 mSv (0.11 rem), or 0.44% of the 10CFR100 siting criterion. A factor of two uncertainty should be applied to account for system design changes. A factor of two uncertainty should be applied to account for system design changes.

The following mitigating systems will be available during and following this accident: the 1E emergency power system, the defense-in-depth containers in the argon cell, the fuel cladding in the air cell, the safety exhaust system with its two stages of HEPA filters, the stack, and the mitigating effects of the site location. The accidents are summarized in Table 8-5.

Table 8-5. Summary of beyond-design-basis accidents.

Beyond-design-based accidents			
Accident	**Energy**	**Material at risk**	**Consequence, site boundary whole body dose equivalent**
Beyond design basis earthquake with resulting metal fire & HEPA filter failures	See DBE event (8.1.1.3)	See DBE event (8.1.1.3)	30% of 10CFR100 criteria
Criticality (10^{18} fissions)	Energy in criticality event	One charge consistent of 18 kg (39.6 lb) Pu	0.44% of 10CFR100 criteria

8.2 Facility Specific Mitigating Features

8.2.1 Argon-Cell Confinement System

The argon cell structure, with its welded-steel liner and sealed penetrations, provides a primary confinement barrier classified as a critical, i.e., safety class system. For all of the components of the argon-cell confinement, including structure, passive penetrations, and active penetrations, the safety function is to provide the primary confinement barrier for radioactive materials within the argon cell under normal operations.

Under all design-basis abnormal conditions, including the DBE, the argon-cell confinement system will maintain its integrity to the extent that potential leakages are within the capability of the SES to prevent unfiltered release of radioactive materials to the environment. The argon-cell confinement system also provides biological shielding for the facility operators. In the case of active penetrations (e.g., large and small transfer locks), the system is capable of purging and evacuating a lock to maintain the integrity of the argon cell atmosphere, as well as controlling the release of radioactive material from the cell.

8.2.2 Diesel Emergency Power System

The emergency power system provides reliable electrical power to the safety exhaust system following the loss of the preferred power source. Under all design-basis abnormal conditions, including the DBE coincident with the loss of preferred power, the emergency power system provides power to the SES. An adequate primary fuel supply is available to ensure the operation of the SES for the burning period of the design-basis fire involving argon-cell process materials.

Following the loss of preferred power, the emergency power system also supplies electrical power to the building exhaust system, the air-cell exhaust system, selected radiation monitors, the confinement differential pressure monitors, the uninterruptible power systems, and, as required, the IBC cooling blower. The shedding of these nonessential loads may be necessary to ensure that the primary fuel supply will operate the diesel generators for the duration of the design-basis fire without backup fuel. An on-site backup fuel supply, designed to avoid damage due to seismic events, will be available to resupply the primary tanks. This backup supply extends the diesel generator operation to supply emergency loads beyond the strict FSAR requirements for accident conditions.

8.2.3 Safety Exhaust System

The SES filters gasborne particles resulting from the design basis fire of argon-cell process material. The SES also mitigates the consequences of overpressures and underpressures in the argon cell.

During an earthquake-initiated, design-basis fire in argon-cell process material, the safety exhaust system prevents unfiltered release through the breaches of the cell confinement boundary, including breaches in the boundary of the subcell recirculation cooling loop enclosures. Radioactive particles exhausted from the cell during this period are filtered by two stages of HEPA filters located in series.

Upon a rise in argon-cell pressure (e.g., following breach of the cell boundary), the SES sense-and-command subsystem provides a signal to electrical trip switches in the bus duct power circuits. These trip switches remove power from all nonessential in-cell heat-producing electrical loads, and all blowers which might either force unfiltered gas out of the cell or force air into the cell. Also, an argon-cell pressure rise causes the automatic damper in the active SES branch to open, initiating exhaust from the cell. The diesel emergency generator starts if normal power is lost.

The overpressure and underpressure relief ensures passive relief through the standby train seal pot before the critical argon-cell boundary is damaged. During periods of maintenance and testing on the SES standby train, the active train provides overpressure protection. Underpressure protection for credible events is provided by the argon supply systems. Events that could result in pressures at or below the negative relief point of the seal pots are judged to be beyond-design-basis events.

Upon failure of the normal pressure control system or loss of the argon-cell cooling system, the SES provides a backup function to prevent a positive argon-cell pressure with respect to other areas of the facility.

8.2.4 Facility Ventilation System

The facility ventilation system consists of the building air supply system, the building exhaust and air cell exhaust systems, and the stack exhaust system. The systems work together to ensure that the entire building is operated at less than atmospheric pressure and to ensure that the air flow within the facility is from clean areas to potentially contaminated areas, then to areas that are contaminated, and finally through HEPA filters to the exhaust stack.

The building exhaust system discharges to the stack exhaust system. Upon a failure of either building exhaust fan, the supply air system is shut down automatically.

The air-cell exhaust system, working in conjunction with the other ventilation systems, develops pressure gradients necessary to prevent the spread of radioactive material from contaminated or potentially contaminated areas to clean areas. The air-cell exhaust system discharges into the stack exhaust system. Upon a failure of either air-cell exhaust fan, the building supply air system is shut down automatically. Since the air-cell exhaust system handles exhaust and vent effluents from contaminated and suspect areas or equipment, exhaust air is passed through at least two stages of in-place DOP-tested HEPA filters before being discharged to the environment via the exhaust stack. A HEPA filter is also installed at contaminated or potentially contaminated space inlet locations and exit locations to provide a barrier against any contamination spread into the air-cell exhaust-system duct work or normally clean spaces. These latter HEPA filters are DOP-testable but are not credited with a decontamination factor.

The stack exhaust system receives gaseous effluents from the EBR-II and the FCF and delivers the mixture by fan power to the 61 m (200 ft) tall stack for discharge to the environment. Discharges are monitored continuously by a stack monitoring system. The guyed, steel stack will withstand loads associated with the DBE, the design basis wind, and the design basis missile but the blowers have not been qualified to assure their operation following a DBE.

8.2.5 Defense-in-depth Containers

The operation of the FCF requires that there be the capability to store subassemblies, individual elements, and fissile material, either while such items are awaiting processing or prior to exiting the facility. The total amount of such items, and their storage locations, are dictated by the criticality hazards control statement.

In the air cell, the primary confinement barrier is fuel cladding or containers. The critical function of storage components in the air cell is ensuring that the primary confinement barrier is not adversely affected. For example, storage racks in the air cell are designed such that adequate passive cooling is obtained, and such that the racks cannot cause mechanical damage to the fuel cladding or container integrity during the DBE.

In the argon cell, the primary confinement barrier is the cell lining. The defense-in-depth function of storage components in the argon cell is ensuring that the contained material does not participate in the argon cell fire. For example, materials storage containers for potentially pyrophoric materials in the argon cell are designed to withstand the DBE and the cell temperatures associated with the argon cell fire. This function both reduces the radioactive and hazardous material at risk of being dispersed and reduces the combustion energy available to disperse the material which is at risk.

8.2.6 Site Location

The ANL-W site is located on the Idaho National Engineering Laboratory in the remote Idaho desert. Any accidental release is isolated from population centers by about 48.2 km (30 miles) of sparsely populated desert and farmland. See Section 3.1 for a brief description of the site location and demographics.

9.0 Transportation

For the preferred immobilization option, weapons usable fissile materials, plutonium, and other TRU elements will be shipped to the site in unclassified forms. Up to three months inventory of feed materials, approximately equivalent to 1 tonne (1.1 ton) of plutonium metal will be stored in the ZPPR. This facility is designed to receive and store fissile materials in these quantities. From ZPPR, the materials to be processed will be sent to the FCF two or three times a week, as needed. Cesium capsules shipped from Hanford are stored in RSWF until they are needed in the FCF to denature the GBZ waste forms. The product waste forms are sent to RSWF for short-term storage until they can be sent to a long-term storage facility or a repository.

9.1 Intrasite Transportation

Normal intrasite transport of highly radioactive materials are listed in Table 9-1. Feeds to the immobilization operations, which take place in the FCF, are (a) surplus plutonium metal transferred from the inventory held in ZPPR; (b) Hanford cesium capsules transferred from the inventory held in RSWF; (c) spent electrorefining salt arising from spent fuel treatment in HFEF; and (d) chloride residues transferred from inventory in ZPPR. This LiCl-KCl-NaCl salt contains fission products and TRU elements from treating spent fuel, and any plutonium obtained by treating TRU-rich residues.

Table 9-2. Intersite transport.

	Input material #1	Input material #2	Output material #1
Transported Materials			
Type	Plutonium	Cesium	Pu/Cs/TRU/fission product ceramic
Physical form	Metal or oxide	Salt	Glass-bonded zeolite
Chemical composition	Pu or PuO_2	CsCl	See Sec. 2.1.1
Packaging			
Type	6M/2R-like	Hanford capsules in BUSSR-1 (C of C #9511)	8 ANL-W canisters in modified DHLW canister
Certified by	DOT/DOE/NRC e.g., Package Certificate of Compliance Number (C of C#) 9966 (SR Chalefant)	NRC/DOE	Not currently certified
Identifier	6M/2R-like	BUSSR-1	5 modified DHLW canisters with the SRS HLW Rail Cask
Package weight	86 to 286 kg (190 to 630 lb)	14.7 tonnes (17 tons)	105 tonnes (116 ton)
Material weight	max of 4.5 kg (9.9 lb) Pu	4.7 kg (10 lb) w/i the BUSSR-1	1040 kg (23,000 lb) of GBZ waste forms with 52 kg (115 lb) Pu per DHLW canister
Isotopic content (%)	93% ^{239}Pu, 6% ^{240}Pu, 1% trace isotopes	56% ^{133}Cs 19% ^{135}Cs 25% ^{137}Cs	5% Pu
Average shipping volume			
Quantity/yr	5 tonnes (5.5 ton) Pu	64 kg (140 lb) Cs	~104 tonnes (115 ton) 5 tonnes (5.5 ton) of Pu
Average Number of packages[1] shipped/yr	1,100	136 Cs capsules	96 modified DHLW canisters
Estimated number of packages[1] shipped over life of the project	11,000	1,360 Cs capsules	960 modified DHLW canisters
Average number of packages[1] per shipment	40	10	1–5 modified DHLW canisters per SRS HLW Rail Cask
Number of shipments/yr	28	14	19 SRS HLW Rail Cask
Number of shipments over the life of the project	280	140	192 SRS HLW Rail Cask
Routing			
Mode of transport:	SST	Commercial truck or rail	Commercial truck or rail
Destination facility type	SNM vault	Shielded vault	Repository

1 Packages are individual quantities of material, not the shipping containers in which multiple packages will be shipped.

10.0 References

Section 1

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Section 5

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EIS	Environmental Impact Study
EM	Environmental Management
EP	Extraction Process
EPA	Environmental Protection Agency
ESH or ES&H	Environment, Safety, and Health
ESRP	Eastern Snake River Plain
ET	Electrometallurgical Treatment
FCF	Fuel Conditioning Facility
FMF	Fuel Manufacturing Facility
FPR	Fuel Processing and Restoration
FSAR	Fuel Safety Analysis Report
gal	gallon
GBZ	glass-bonded zeolite
HEPA	High Efficiency Particulate Air (Filter)
HFEF	Hot Fuel Examination Facility
HRF	Hot Repair Facility
HVAC	Heating, Ventilation, Air Conditioning
HWSF	Hazardous Waste Storage Facility
IBC	Inter-Building Cask
ICPP	Idaho Chemical Processing Plant
ICRP	International Committee on Radiological Protection
IEEE	Institute of Electrical and Electronics Engineers
IFR	Integral Fast Reactor
ILTSF	Intermediate Level Transuranic Storage Facility
IMF	Instrument and Maintenance Facility
INEL	Idaho National Engineering Laboratory
kg	kilograms
kW	kilowatts
KD	key decision
LLW	low level waste
LOB	Laboratory & Office Building
LWR	Light Water Reactor
m^3	cubic meters
MAA	Material Access Area
MS	Material Surveillance
MSSA	Master Safeguards and Security Agreement

MT	metric tons
MTS	Mass Tracking System
MWh	Megawatt-hours
N/A	not applicable
NEPA	National Environmental Protection Act
NERP	National Environmental Research Park
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
OOS	ANL Office of Operational Safety
ORR	Operational Readiness Review
PA	Protected Area
PEIS	Programmatic Environmental Impact Statement
ppm	parts per million
PSD	Prevention of Significant (Air Quality) Deterioration
Pu	plutonium
PuO	plutonium oxide
PUREX	Plutonium Uranium Recovery by Extraction
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act of 1976
RLWTF	Radioactive Liquid Waste Treatment Facility
RMWSF	Radioactive Mixed Waste Storage Facility at INEL
ROD	record of decision
RRWAC	Reusable Property, Recyclable Materials, and Waste Acceptance Criteria
RSWF	Radioactive Scrap and Waste Facility
RWMC	Radioactive Waste Management Complex
SAR	Safety Analysis Report
scfm	standard cubic feet per minute
SEB	Safety Equipment Building
SES	Safety Exhaust System
SHADE	Shielded Hot Air Drum Evaporator
SNM	Special Nuclear Material
SPERT	Special Power Excursion Reactor Test Area

TBD	to be determined
TLV	Threshold Limit Value
TRU	transuranic (referring to elements heavier than uranium)
TSA	Transuranic Storage Area at INEL
TSD	Treatment, Storage, or Disposal
WERF	Waste Experimental Reduction Facility
WHM	Waste Handling Manual
WIPP	Waste Isolation Pilot Plant
yd^3	cubic yards
yr	year
ZPPR	Zero Power Physics Reactor

Category I	A designation of quantities of special nuclear material as defined in the DOE graded safeguards system. Category I facilities fall in the highest class of DOE safeguards and securities provisions.
DOE Spent Fuel Treatment Program	An ongoing program of electrometallurgical treatment of spent fuel from a variety of DOE reactors in preparation for interim storage or final disposition. The first phase of this program involves the treatment of spent fuel from EBR-II.
EBR-II	Experimental Breeder Reactor-II, the second in a series of sodium-cooled, fast-spectrum, experimental reactors built in the early 1960s and located at the ANL site on the Idaho National Engineering Laboratory reservation east of Idaho Falls, ID.
FCF	Fuel Conditioning Facility: A remotely operated shielded facility, to be used for the immobilization of surplus weapons-grade fissile material. This facility was previously identified as HFEF-South.
HEPA	High efficiency particulate air, the standard filter media used for removing airborne radioactive particles from exhaust gases.
HFEF	Hot Fuel Examination Facility: A remotely operated shielded facility, to be used to support the immobilization operations in FCF.
Mass Tracking System	A near-real-time computerized system that tracks the location and movement of controlled materials, and updates the database whenever the location, configuration, or composition of a tracked item changes.

Pyrophoric	Some metals with sufficient surface to volume ratio and at sufficiently high initial temperatures are capable of spontaneous ignition. Such materials are said to be pyrophoric.
Master Safeguards & Security Agreement	A site-specific document governing the safeguards and security provisions to be applied to protect special nuclear material and vital equipment.
Safety Class	A classification of systems, components, and structures, including portions of process systems, whose failure could adversely affect the environment or safety and health of the public. Determination of classification is based on analysis of the potential abnormal and accidental scenario consequences as presented in the safety analysis report.
SES	Safety Exhaust System: A dual-train HEPA-filtered system for relieving overpressure in the FCF argon cell and preventing unfiltered outflow in the event of a cell breach.
ZPPR	Zero Power Physics Reactor: A facility originally used for reactor physic measurements; now used for storage of ton-quantities of weapons-usable plutonium (these qualify as Category I).