Document ID: PSD 4.12
Revision ID: 21
Effective Date: 11/17/03

Plant Safety Document

Irradiated Fuel Storage Facility

INEEL

Idaho National Engineering and Environmental Laboratory

Form 412.14
10/09/2003
Rev. 05

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
21	9/03	All	E. D. Sellers, letter to R. L. Loos, "U.S. Department of Energy, Idaho Operations Office (NE-ID) Approval of Safety Documents for the Receipt of Foreign Research Reactor Fuel from Japan (INTEC-SNF-03-062)," September 16, 2003, CCN 45055.
20	8/03	All	E. D. Sellers letter to R. R. Chase, "NE-ID Approval of Safety Documentation for the Receipt of Oak Ridge Spent Fuel Shipments 4 and 5," (INTEC-SNF-03-054), CCN 44700, August 28, 2003.
			E. D. Sellers letter to R. R. Chase, "NE-ID Approval of Safety Documentation for the Receipt of General Atomics Fuel at the Idaho Nuclear Technology and Engineering Center," (INTEC-SNF-03-052), CCN 44701, August 28, 2003.
19	6/03	All	M. Christine Ott Letter to R. R. Chase, "DOE-ID Approval of Revisions to Plant Safety Document Revisions for the Receipt of Spent Nuclear Fuel from Oak Ridge (INTEC-SNF-03-034), CCN 43050, dated June 6, 2003.
18	4/03	All	M. Christine Ott Letter to R. R. Chase, "DOE-ID Approval of INTEC Plant Safety Document Section 4.12, Addendum I and Associated Technical Standards for the Receipt of PBF Fuel at the Irradiated Fuel Storage Facility (INTEC-SNF-03-004), CCN 41406, dated April 4, 2003.
17	10/02	Chapter 8	W. E. Bergholz, Jr., Letter to R. R. Chase, "DOE-ID Approval of Safety Documents for Use of the NAC-LWT Cask at the INTEC Irradiated Fuel Storage Facility (INTEC-SNF-02-080)," dated October 28, 2002.
16	10/02	Chapter 8	W. E. Bergholz, Jr., Letter to R. R. Chase, "DOE-ID Approval of Safety Documents for the Transfer of Peach Bottom Fuel from the CPP-603 Fuel Element Cutting Facility (FECF) to the Irradiated Fuel Storage Facility (IFSF) (INTEC-SNF-02-077)," dated October 8, 2002.
	09/02	Chapter 8	W. E. Bergholz, Jr., Letter to R. R. Chase, "DOE-ID Approval of Safety Documents for the Receipt of Spent Nuclear Fuel from Oak Ridge (INTEC-SNF-02-072)," dated September 13, 2002.
15	04/02	All	W. E. Bergholz, Jr., Letter to R. R. Chase, "DOE-ID Approval of INTEC Plant Safety Document Revisions for the Receipt and Storage of MTR Canal Fuel at the Irradiated Fuel Storage Facility (INTEC-SNF-02-026)," dated April 12, 2002.
14	06/01	Sec. 8 & 9	R. M. Stallman, Letter to Arthur Clark, "DOE Approval of Safety Documents for the Receipt of Foreign Research Reactor Fuel from Germany and Resolution of the CPP-603 Transfer Car Sliding Saddle Unreviewed Safety Question (INTEC-SNF-01-041)," dated June 8, 2001.
13	08/99	All	R. M. Stallman, Letter to J. E. Hovinga, "DOE Approval of

Rev.	Date	Affected Pages	Revision Description
			Foreign Reactor Safety Documents and Unreviewed Safety Question (OPE-INTEC-99-070)," dated August 25, 1999.
	07/99	All	R. M. Stallman, Letter to J. E. Hovinga, "DOE Approval of Seismic Safety Document Revisions for the Irradiated Fuel Storage Facility (OPE-INTEC-99-055)," dated July 2, 1999.
	06/99	All	R. M. Stallman, Letter to J. E. Hovinga, "DOE Approval of Irradiated Fuel Storage Facility (IFSF) Safety Document Revisions for Unreviewed Safety Question Resolution (OPE-INTEC-99-47)," dated June 21, 1999.
12	05/99	All	R. M. Stallman, Letter to J. E. Hovinga, "DOE Approval of ROVER PARKA Fuel Safety Documents (OPE-INTEC-99-35)," dated April 29, 1999.
11	03/99	All	R. M. Stallman, Letter to J. E. Hovinga, "DOE Approval of WAPD, BMI-Spec, and TRIGA-Al Instrumented Fuels Safety Document Revisions (OPE-INTEC-99-019)," dated March 17, 1999.
10	12/98	All	R. M. Stallman, Letter to B. H. Hamilton, "DOE Approval of Irradiated Fuel Storage Facility Safety Documents (OPE-INTEC-98-110)," dated November 6, 1998
10	12/98	All	R. M. Stallman, Letter to B. H. Hamilton, "DOE Approval of TRIGA-Al Safety Document Revisions (OPE-INTEC-98-124)," dated November 25, 1998.
9	04/98	All	R. M. Stallman, Letter to T. A. Mathews, "DOE Approval of Safety Documents for the Receipt of Foreign Research Reactor Fuel (OPE-INTEC-98-083)," dated July 16, 1998.

CONTENTS

FIGURES

TABLES

ACRONYMS

ALARA	as low as reasonably achievable
ARF	airborne release fractions
ARMF	Advanced Reactivity Measurement Facility
ATR	Advanced Test Reactor
BER-II	Berliner Experimentire Reactor II
BMI-Spec	Battelle Memorial Institute Specimen
CAM	continuous air monitor
CAS	criticality alarm system
CFRMF	Coupled Fast Reactivity Measurement Facility
CSE	criticality safety evaluation
DBE	design basis earthquake
D/C	demand to capacity
DCG	derived concentration guide
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Operations Office
DP	differential pressure
EBR-II	Experimental Breeder Reactor II
ECC	Emergency Control Center
EDE	effective dose equivalent
FAST	Fuel Storage (facility)
FDCS	Fuel Storage Distributed Control System
FHU	Fuel Handling Unit
FSB	Fuel Storage Basins (CPP-603)
FSV	Fort St. Vrain
GM	Geiger-Muller
GSF	Graphite Storage Facility
GUI	graphical user interface
HEPA	high-efficiency particulate air
HFBR	High-Flux Beam Reactor
HTGR	high-temperature gas-cooled reactor

I/O	input and output
ICBO	International Conference of Building Officials
INEL	Idaho National Engineering Laboratory
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
INTEC SAR	Idaho Nuclear Technology and Engineering Center Safety Analysis Report
IFSF	Irradiated Fuel Storage Facility
KAPL	Knolls Atomic Power Laboratory
MCC	motor control center
MPA	maximum postulated accident
MTR	Materials Test Reactor
MURR	Missouri University Research Reactor
NAD	nuclear accident dosimeter
NIST	National Institute of Standards and Technology
NRBK	Naval Reactor Bettis KAPL
ORR	Oak Ridge Research Reactor
OSR	operational safety requirement
PCS	permanent containment structure
PEW	process equipment waste
PM	preventative maintenance
PSD	Plant Safety Document
RAM	radiation area monitor
RCT	radiological control technician
SAR	safety analysis report
SARP	safety analysis report for packaging
SS	stainless steel
Tory	Experimental Propulsion Test Reactor
TRA	Test Reactor Area
TRIGA	training, research, and isotope reactors
TS	technical standard
TV	television
WAPD	Westinghouse Atomic Power Division
UBC	Uniform Building Code
UBM	uranium bearing material

1. INTRODUCTION

CONTENTS

TABLE

1. INTRODUCTION

This safety analysis report (SAR) pertains to the Irradiated Fuel Storage Facility (IFSF), a nuclear fuel storage facility located in the Fuel Receiving Storage Facility (CPP-603) at the Idaho Nuclear Technology and Engineering Center (INTEC), which is part of the Idaho National Engineering Laboratory (INEEL). The IFSF, formerly known as Graphite Storage Facility (GSF), was constructed at the INTEC to provide safe storage for spent, high-temperature, gas-cooled reactor (HTGR) fuels. HTGR fuels, as well as other types of fuel, are also stored at the Underground Storage Facility (CPP-749). A description of the Underground Storage Facility appears in Idaho Nuclear Technology and Engineering Center Safety Document (PSD) Section 4.7.[1,2]

Initially three graphite-based fuels were approved for storage at the IFSF: Rover-type fuels, Peach Bottom Core I, and Fort St. Vrain. Two nongraphite fuels, Experimental Propulsion Test Reactor (Tory) IIC and Berliner Experimentire Reactor II (BER-II) training research and isotope reactors (TRIGA), also were approved for storage. Subsequently, additional nongraphite fuels some of which were processed in the Fuel Canning Station and Rover uranium bearing material (UBM), as defined below, were added to the list of fuels approved for storage in the IFSF. Table 1-1 shows all of the fuel types and compositions that are handled and stored at the facility. The safety analysis for handling and storage of unirradiated Rover fuel in the IFSF is presented in Addendum A to this SAR.[3] The safety analysis for the Fuel Canning Station, located in the IFSF handling cave, is presented in Addendum B to this SAR.[4,5,6]

The approved fuels, listed in Table 1-1, are stored in the IFSF because they are unsuitable for long-term underwater storage. Potential reactions with water preclude safe storage in a water medium for many of these fuels. Even the use of leakproof metallic canisters for underwater fuel containment is not suitable because the possibility of corrosion or loss of integrity of a sealing gasket increases with time. Corrosion of fuel and storage devices is minimal in the IFSF because of the dry environment and the constant circulation of the low humidity outside air from the INEEL environment.

Some aluminum clad and other fuels originally intended for reprocessing are also stored in the IFSF. These fuels were stored under water for an intended limited time but because of cladding corrosion, they are not suitable for extended underwater storage.

Peach Bottom and Fort St. Vrain fuels consist of uranium and thorium carbide microspheres coated with pyrolytic graphite and silicon carbide and dispersed in a graphite matrix. Except for the absence of thorium carbide, Rover fuel is chemically similar to Peach Bottom and Fort St. Vrain fuels. Dry storage is required because, if the graphite matrix were damaged to the extent that the carbide microspheres were exposed to water, the carbides would react with water to form hydrocarbons (primarily methane and acetylene) and metallic oxides. The reaction is relatively fast, and the accompanying volume expansion resulting from the carbide conversion could rupture the storage canisters, releasing fission products into the surrounding water.

Table 1-1. IFSF fuel types and composition listing.

Fuel Type	Fuel Composition
Advanced Reactivity measurement Facility (ARMF)	UAl_x, Al clad
Advanced Test Reactor (ATR)	UAl_x, Al clad
Battelle Memorial Institute Speciman (BMI-Spec)	UMo, nickel-plated, Al clad
Berliner Experimentire Reactor II (BER-II)	U-ZrH, ss clad
Coupled Fast Reactivity Measurement Facility (CFRMF)	UAl_x, Al clad
Coupled Fast Reactivity Measurement Facility (CFRMF) Core Filter	Depleted U block with 93% enriched annular area, no cladding
Experimental Breeder Reactor II (EBR-II)	U, SS clad
Foreign Research Reactor (FRR) Training, Research, and Isotope Reactors (TRIGA) (includes both foreign and domestic TRIGA research reactor fuels)	U-ZrH, cladding is either Al, SS, or Incoloy
Fort St. Vrain	Graphite (UC, ThC)
High-Flux Beam Rector (HFBR)	UAl_x, U_3O_8, Al clad
Materials Test Reactor (MTR) Canal	UO2, metal cladding; some unclad pellets; metallography mounts, fuel rods, rod sections, and test trains in various potting compounds
Missouri University Research Reactor (MURR)	UAl_x, Al clad
Oak Ridge Research Reactor (ORR)	UAl_x, U_3O_8, Al clad
Peach Bottom	Graphite (UC, ThC)
Rover Fuel	Graphite (UC)
Rover UBM	U_3O_8; alumina bed material; metal fines; HEPA filter media; one 6-inch fuel rod (UC); partially burned graphite; other non-fuel material in small amounts
Tory IIC	BeO (UO_2, Y_2O_3, ZrO_2)
TRIGA-Al(including TRIGA-Al Instrumented, which is hereafter referred to only as TRIGA-Al)	U-ZrH, Al clad
Westinghouse Atomic Power Division (WAPD)	UO_2, ss clad, NaK between cladding sheaths

Rover UBM is material derived from the headend (dry side) of the Rover fuel reprocessing campaign of 1983-84. At the completion of the campaign, significant quantities of Rover UBM remained in the headend process area. As part of the Rover deactivation, the Rover UBM is removed from the process and canned at CPP-640 prior to transfer to the IFSF or another dry storage facility. Although Rover UBM is derived from Rover fuel, it has been partially processed and also includes bed and other material. Originally, the Rover fuel was in carbide form, but the burning process converted the fuel material primarily to uranium oxide. Therefore, Rover UBM is considered separately from Rover (or Rover-like) fuel in this report. Note that some cans from the Rover process contain partially burned graphite, floor sweepings, or other moderator material in significant amounts. All individual can contents from the Rover process are analyzed, documented, and tracked.

Tory IIC and BER-II TRIGA fuels contain beryllium oxide and zirconium hydride, respectively. Other fuels, like BMI-Spec and Westinghouse Atomic Power Division (WAPD), can react with water forming sodium hydroxide and hydrogen or uranium oxides and uranium hydrides from U-metal. These can also result in volume expansion and rupture and, therefore, potential fission product release.

1.1 Summary

This subsection provides a brief summary of the conclusions of evaluations of various safety aspects of IFSF operations.

This SAR addresses the facility and fuel responses to the design heat load. The current heat load is significantly less than design because of the reduced burnup and delayed receipt of fuel, which results in both a partially filled facility and longer cooling times. The storage of fuels processed in the Fuel Canning Station is enveloped by the previous evaluations of fuels with all of the available storage positions being filled.

The types of potential hazards that may be encountered in the IFSF operations are nuclear criticality, breach of confinement that could result in radiation exposure or radioactivity release, fire and explosion, and chemical and industrial hazards. The fuel contains large amounts of fission products and highly enriched uranium. Some fuels could react with water forming sodium hydroxide, hydrogen, organic acids, methane, and uranium hydrides or oxides. These could release potentially explosive gases or could incur pyrophoric reactions. All of the potential hazards listed above have been addressed in the analyses, and actions that mitigate the hazards are detailed in this report. Approved fuels can be received, handled, stored, and removed from the facility safely.

Two or more barriers are generally imposed to limit releases to either the plant area or the external environment. These barriers limit exposures to facility workers to as low as reasonably achievable (ALARA) levels during normal operation and exposures to collocated workers and the public (off-site) to within applicable standards during normal or abnormal operating conditions. The primary methods for preventing a nuclear criticality in the IFSF system are moderator, geometry, and uranium mass controls.

The IFSF facility was designed and built in the early 1970s. Beginning in 1996, several seismic analyses were performed. Modifications were made where necessary to ensure that current seismic acceptance criteria are met. Details of the analyses and discussions of their results are given in Subsections 3.3.7 and 8.1.1.

The facility will withstand the wind loads specified for this type of facility and location; however, some missile damage to ventilation ducting outside the north wall and to the shield door enclosure is possible.[6] This could lead to an interruption of the cooling airflow. It is expected that cooling can be readily restored within less than the 22 days allowable for this function to be out of service (see Subsection 8.2). Interruption of shield door operation above the interior shield wall is an operational inconvenience rather than a safety issue.

The analysis of possible abnormal occurrences within the IFSF (see Subsection 8.5), concluded that only a few of the consequences might be significant outside the IFSF. IFSF shielding and ventilation systems mitigate these consequences. As a result, the consequences to INTEC personnel and the public meet applicable Department of Energy (DOE) standards. Also, within the IFSF, the precautions against the starting and spreading of fire are sufficient to prevent the spread of radioactivity caused by the occurrence of a fire.

Although the IFSF accident evaluation revealed no significant risk in the IFSF system (see Subsection 8.6), a nuclear excursion in the fuel handling cave was chosen for evaluation of the facility for maximum potential undesirable consequences. The results are within the limits established for accident conditions. Criticality accidents involving cask handling operations in the cask receiving area are evaluated in the respective cask handling safety documents as necessary.

The following conclusions may be drawn about the residual risk in the operation of the facility. First, the possibility of an accidental criticality in the IFSF is extremely unlikely. Second, the facility is designed to prevent contamination (fission product and alpha) spreading from the IFSF shielded area to areas occupied by people. Postulated nuclear, chemical, or radiological accidents in the IFSF are adequately controlled or would have consequences that are within allowable limits, and are considered to present no unacceptable risk.

Because there is the potential for a criticality accident and because of the significant radionuclide inventory in the IFSF, the facility is assigned a Hazard Category 2 classification.

1.2 References

1. Lockheed Martin Idaho Technology Company, Idaho Nuclear Technology and Engineering Center Safety Document, WIN-107.

2. PSD, Section 4.7, "Underground Fuel Storage."

3. PSD 4.12A, "Safety Analysis Report Receipt and Storage of Unirradiated ROVER and TREAT Fuel at the Irradiated Fuel Storage Facility."

4. PSD 4.12B, "CPP-603 IFSF Fuel Canning Station."

5. PSD 4.12B-Sup, "ARMF and CFRMF Fuels."

6. PSD 4.12F, "CPP-603 IFSF Foreign Research Reactor TRIGA Fuel Handling and Storage."

2. FUELS DESCRIPTION

CONTENTS

FIGURES

TABLE

2. FUELS DESCRIPTION

This section provides a general description of materials currently handled and stored at the IFSF. The physical and chemical characteristics (radiation, decay heat, etc.) that impact safety are discussed in Section 8. Additional data on fuels may be found in the fuel receipt criteria documents maintained by the INEEL Nuclear Fuel Operations Department and in the Rover SAR.[1] All enrichments reported in this document are beginning-of-life (BOL) values.

2.1 Peach Bottom Fuel

A Peach Bottom fuel element (Figure 2-1) is 144 in. long, 3.5 in. in diameter and weighs approximately 75 lb. Each element consists of an upper reflector section, a fuel-bearing center section, a lower reflector section, and an internal fission product trap. The upper reflector assemblies of the Peach Bottom fuel elements were cut off in the IFSF to allow them to fit in an IFSF storage canister. Some Peach Bottom elements were broken, and these broken elements are likewise stored in the IFSF in canisters.

All components of a Peach Bottom element are constructed of graphite except (1) the fuel compacts, or the meat, contained in the fuel-bearing center Section, (2) the burnable poison compacts placed in the hollow center spines of certain elements, and (3) a small stainless steel screen installed at the bottom of each fission product trap assembly to retain any charcoal granules that might be released from the graphite body of the internal trap. The fuel compacts originally (before irradiation) consisted of uranium carbide (93.15% enriched) and thorium carbide substrates coated with graphite and uniformly dispersed as particles in a graphite matrix. The burnable poison compacts contain natural boron in the form of zirconium diboride pressed into a graphite matrix. Peach Bottom core I and core II fuels are similar except for minor differences in fuel meat composition and particle coating. The most reactive fuel element (before burnup) has the following composition (compacts only):

Th-232	1.56 kg
U-234	0.005 kg
U-235	0.291 kg
U-236	0.002 kg
U-238	0.015 kg
Rh-103	0.006 kg
Carbon	8.55 kg

2.2 Fort St. Vrain

A Fort St. Vrain fuel element (Figure 2-2) is a 320-lb-hexagonal, needle-coke-graphite block. The block is 14.1 in. across the flats of the hexagon and is 31.2 in. high. Each graphite fuel block contains 108 coolant channels and 210 fuel holes, all drilled from the top face of the element. The coolant holes extend through the element; the fuel holes extend to within 0.3 in. of the bottom face. The fuel holes are spaced in alternating positions with the coolant channel holes in a triangular array within the element structure, and the active fuel is inserted in the fuel holes. After the fuel is inserted into a fuel hole, the

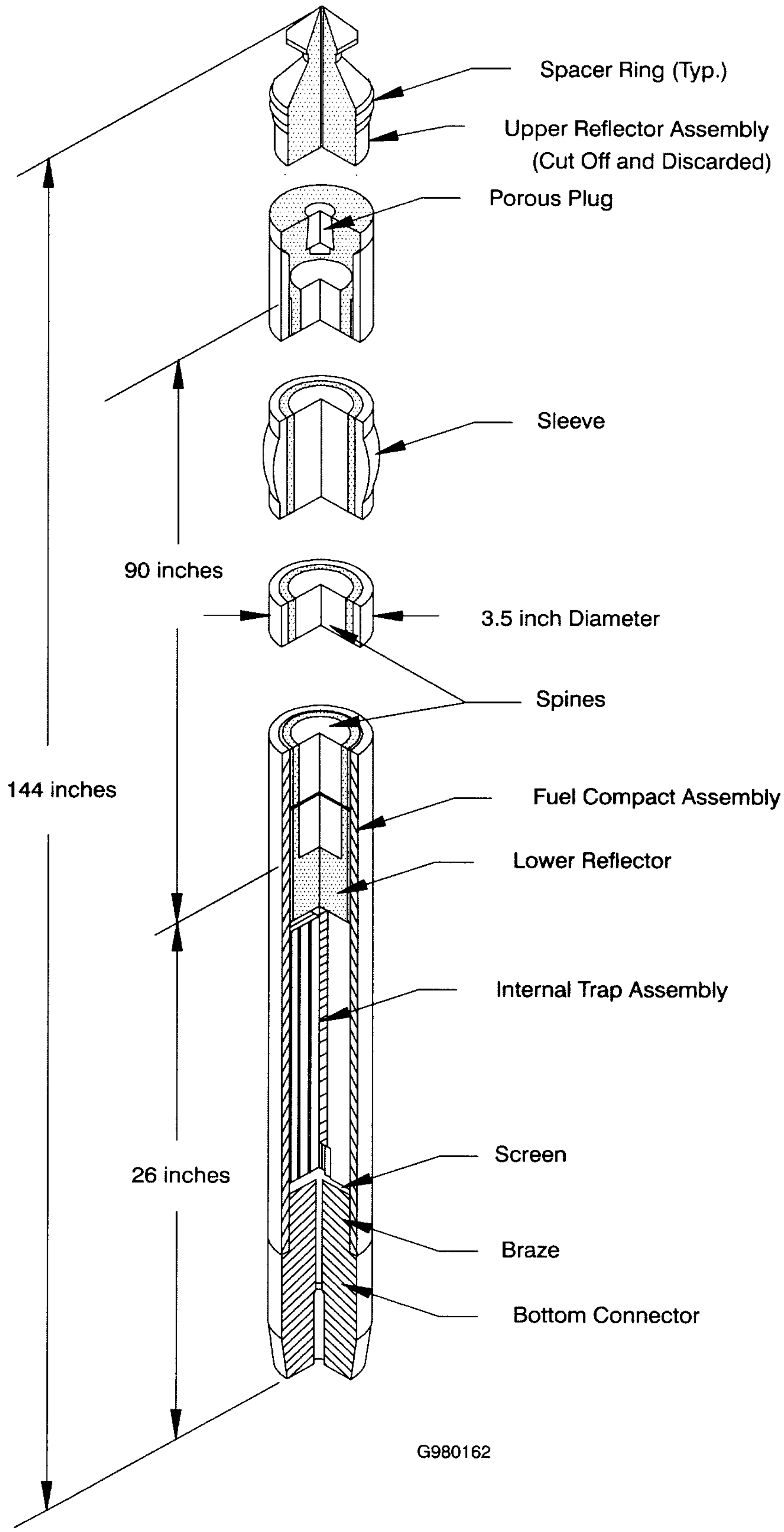

Figure 2-1. Peach Bottom fuel element.

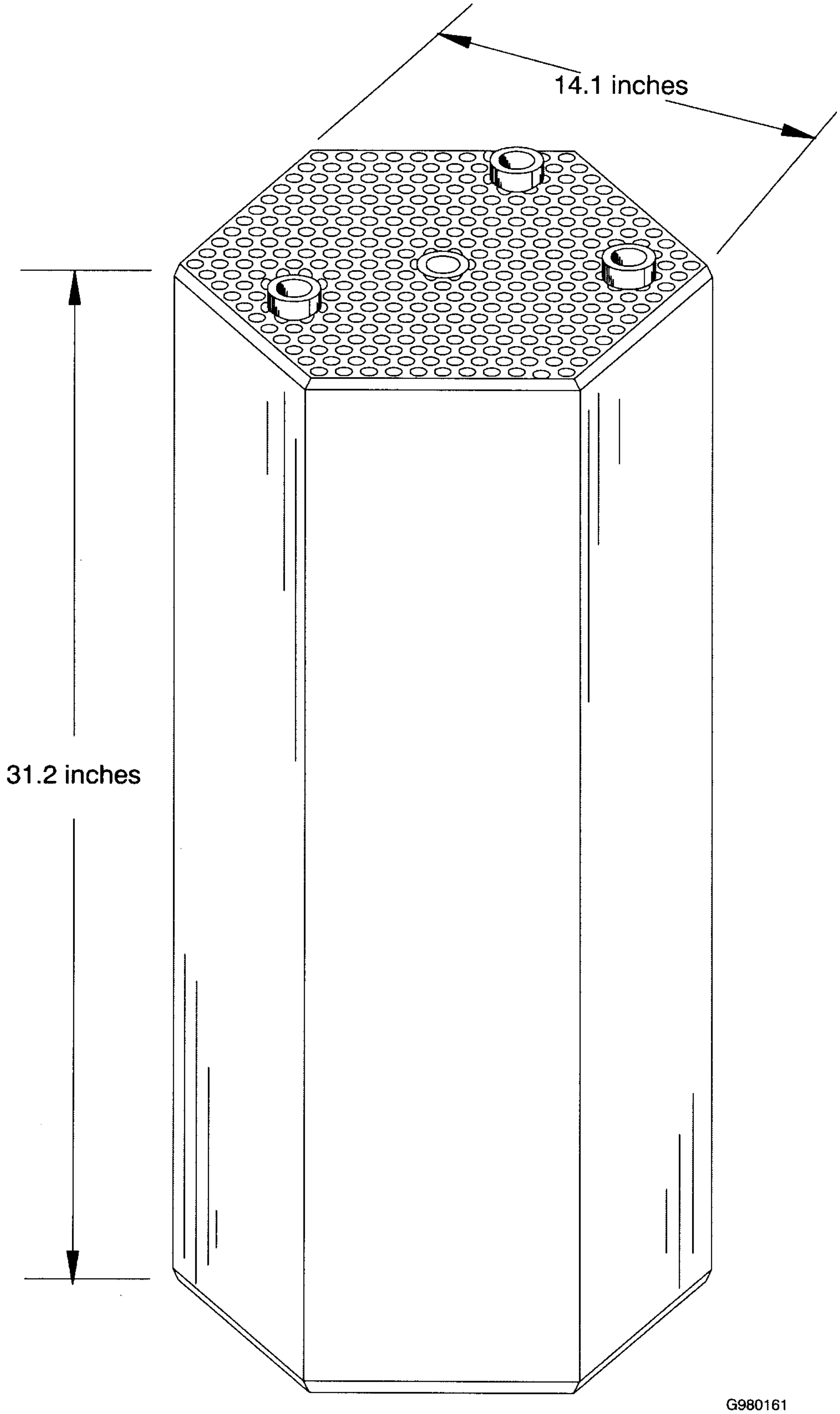

Figure 2-2. Fort St. Vrain fuel element.

hole is sealed with a graphite plug cemented into place. Up to four Fort St. Vrain fuel elements are stored per IFSF canister.

The unirradiated fuel is in the form of uranium carbide particles coated with layers of pyrolytic graphite and silicon carbide, loosely bonded by a carbonaceous matrix material into fuel sticks. The fuel contains a mixture of two types of particles, fissile and fertile. Fresh fissile particles contain thorium and 93.5% enriched uranium $(Th/U)C_2$; fresh fertile particles contain only thorium (ThC_2).

The effective fissile material enrichment ($^{235}U/U+Th$) in fresh fuel (before burnup) for the initial core and reload segments varies between 2% and 12%, depending upon radial and axial fuel zoning requirements. Fresh fuel elements have the following composition:

Th-232	24.8 lb
U-235	2.9 lb
U-238	0.2 lb
Silicon	10.0 lb
Carbon	282.1 lb

2.3 Rover-Type Fuels

A Rover-type fuel is a graphite matrix dispersion fuel consisting of pyrolytic carbon-coated or uncoated uranium dicarbide fuel particles. The fuel is in the form of hexagonal rods. A Rover fuel rod is 52 in. long and 0.75 in. across the flats of the hexagon, as illustrated in Figure 2-3. There are three types of Rover fuel rods: regular, composite, and high-fired. The regular rods contain mixed uranium and niobium carbides dispersed in a graphite matrix. The composite rods contain carbides of zirconium rather than niobium. The high-fired rods are similar to composite rods but are impregnated with ZrC during the final step of fabrication. Rover-type fuels are stored in cardboard tubes in inserts within IFSF storage canisters. Rover-type fuels may also be repackaged and stored in metal tubes. The repackaging into and handling of Rover fuel in metal tubes is described in Section 7.1. The composition of each type of Rover fuel and a general description of the original handling and storage of unirradiated Rover fuel are contained in Addendum A to this SAR. Rover fuel handling, storage, and removal methods and requirements that are additional to those discussed in Addendum A are presented in Section 7.

2.4 Tory IIC

A Tory IIC fuel element is a ceramic tube containing 45 wt% UO_2, 35.6 wt% Y_2O_3, and 19.4 wt% ZrO_2 in a BeO matrix. The majority of tubes are 4 in. long (approximately 20% are shorter), hexagonal in cross section, and 0.3 in. across the flats of the hexagon, and have an inside diameter of 0.23 in. The UO_2 content per tube ranges from 1.2 to 8.1%. Uranium enrichment is 93%.

Tory IIC fuel received at the INTEC is in the form of crushed ceramic elements, approximately 0.25x0.25-in.-sized particles packaged into 2.5-in.-diameter aluminum cans compacted to at least 70% solid volume fraction in the can. The cans are stored in canister inserts within IFSF storage canisters. The ^{235}U loading per can ranges from 104 g to 179 g. An insert may contain up to 15 cans and each canister may contain up to two inserts.

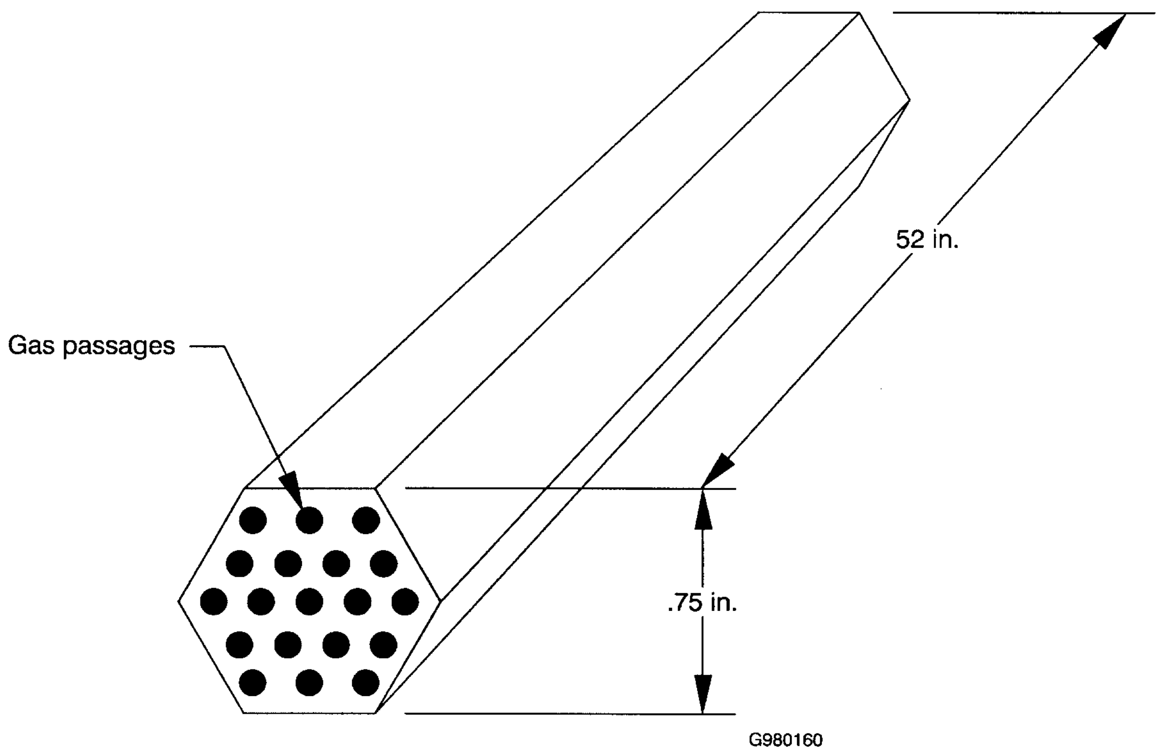

Figure 2-3. Rover fuel rod.

2.5 BER-II TRIGA

BER-II TRIGA fuel elements consist of an array of tubes held together by end boxes. There are three types of BER-II TRIGA fuel elements: standard elements, containing 16 fuel rods; control elements, containing eight fuel rods; and instrumented elements, containing 16 fuel rod elements with attached Ni-Cr thermocouples. Each element weighs approximately 44 lb. Table 2-1 shows the chemical composition of the meat of the various types of unirradiated BER-II TRIGA fuel elements. Enrichment is 44 wt%. BER-II TRIGA fuel elements are stored in canister inserts within IFSF storage canisters.

Table 2-1. Chemical Composition of a BER-II TRIGA Fuel Element (kg/element).

	Zr	H	U (Total)
Standard	5.308	0.096	0.499
Control	2.654	0.048	0.249
Instrumented	4.943	0.089	0.466

2.6 Canning Station Fuels

A description of the fuels processed in the Fuel Canning Station is in Addendum B to this SAR. The fuel types in this category are Advanced Test Reactor (ATR), Missouri University Research Reactor (MURR), Oak Ridge Research Reactor (ORR), High-Flux Beam Reactor (HFBR), Battelle Memorial Institute Specimen (BMI-Spec), Westinghouse Atomic Power Division (WAPD), TRIGA, and Advanced Reactivity Measurement Facility (ARMF) and Coupled Fast Reactivity Measurement Facility (CFRMF). These fuels are stored in fuel-specific configurations.

2.7 Rover Uranium Bearing Material

Rover UBM is distinct from Rover fuels. As such, Rover UBM will always be referred to explicitly as Rover UBM in this document, whereas Rover fuels will be referred to explicitly as fuels.

The CPP-640 Rover dry headend process burned tubes of Rover fuel (see above) in two burners in succession before transferring the resulting uranium-bearing ash to a chemical dissolution (wet) process. The campaign was completed, with unirradiated fuel tubes charged to the primary burner last, as planned, in order to facilitate future cleanout. Significant quantities of Rover UBM, both irradiated and unirradiated, remained in the dry side process area, primarily in the burners and one smaller intermediate vessel. In order to eliminate the risk of criticality and deactivate the dry area, the Rover UBM is removed from the process and canned at CPP-640 in preparation for dry storage. The SS Rover UBM can is depicted in Figure 2-4. Rover UBM consists primarily of the burned Rover ash, burner bed material, miscellaneous material originally shipped with the Rover fuel in cardboard fuel tubes and charged to the burners, and any filters, metal fines or miscellaneous material that bears significant embedded Rover UBM.

Rover UBM is heterogeneous in physical properties, composition, density, extent of radiation and contamination hazards, and amount of fissile material. Therefore, as cans are filled with Rover UBM at the CPP-640 facility, representative samples are obtained and analyzed and each can is weighed. Overall burnup was in the range of 0 to 0.04%. Heat generation is estimated at 0.0035 watts per can.[2]

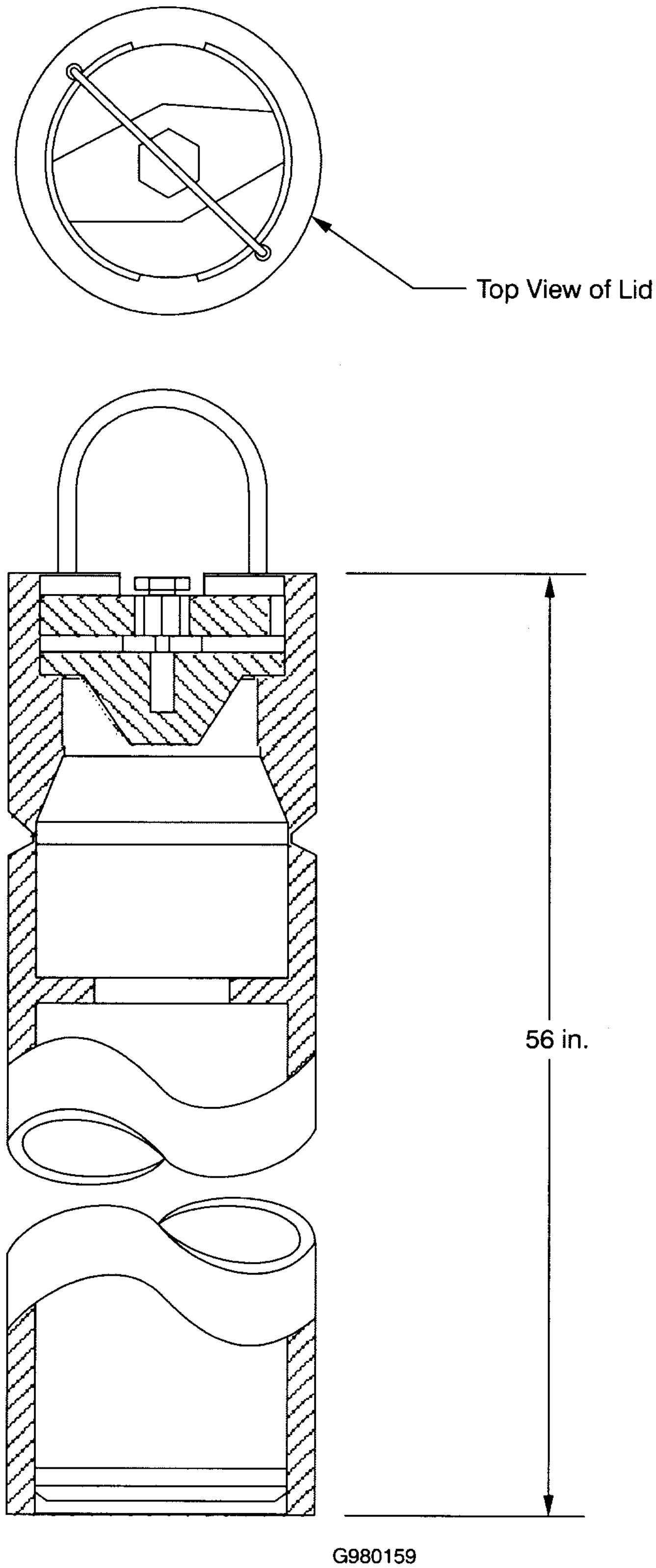

Figure 2-4. Rover UBM can (CAN-SF-1XX) and lid.

Most of the Rover UBM will consist of alumina bed material from the Rover process primary and secondary burner vessels. Based on sample results,[3,4] the burner material is estimated to contain 2 to 25 wt% ^{235}U and produces radiation fields up to 4 R/h on can contact, with a median of about 1.2 R/h. A number of cans may contain sintered metal filter or high-efficiency particulate air (HEPA) filter media with embedded ^{235}U. One can contains one UHTREX 6-in. uranium carbide fuel rod. A few cans will contain Rover ash from a much smaller intermediate vessel (Rover vessel 102) with 7 to 12 wt% ^{235}U, except for one can with portions up to about 45 wt% ^{235}U. All but the last can from this smaller vessel produce radiation fields no higher than 5 R/h. The last can contains a small hot spot, but is indistinguishable from the 5 R/h cans at 1 m. Cans from another vessel (Rover vessel 101) contain up to 35 wt% partially burned graphite, less than 3 wt% ^{235}U, and read 0.5 R/h or less. The Rover UBM fuel movement plan assumes that no cans will require special handling.[5] However, any radiation fields which are higher than expected will be evaluated on a case by case basis for special handling and ALARA issues. The uranium in Rover UBM is approximately 93% enriched. Rover UBM is further described in Addendum A to PSD 5.5[6] and in the Fuel Receipt Criteria on file with the Fuel Receipt Coordinator.

2.8 FRR TRIGA Fuels

Descriptions of the FRR TRIGA fuels (which include both foreign and domestic TRIGA research reactor fuels) are in Addendum F to this SAR. As detailed in the "Characterization of TRIGA Fuel" report,[7] the same TRIGA fuel was used in both domestic and foreign reactors. "FRR TRIGA" was the term originally used in this PSD to describe the TRIGA fuel type received from foreign TRIGA reactors at the IFSF. Four TRIGA fuel types/configurations were originally approved for receipt at the IFSF during the FRR receipt program, including: (1) FRR TRIGA-SS FLIP in NAC-LWT baskets, (2) FRR TRIGA-Al or Standard FRR TRIGA-SS in NAC-LWT baskets, (3) FRR TRIGA-IN in NAC-LWT baskets, and (4) FRR TRIGA-Al or Standard FRR TRIGA-SS in BEL cans. This safety analysis and the associated supporting evaluations for the FRR TRIGA receipts are applicable for any TRIGA fuel meeting the fuel criteria and package configurations assumed for the FRR TRIGA fuel. Therefore, the term "FRR TRIGA" is expanded herein to encompass any TRIGA fuel, foreign or domestic, that meets the fuel criteria and package configurations as originally established for the foreign TRIGA fuel receipts. The term FRR TRIGA is preserved in this PSD to prevent confusion when referring to the previously established fuel records, criticality safety evaluations, engineering design documents, etc.

FRR TRIGA fuel rods of uranium zirconium hydride are clad in either aluminum, stainless steel, or Incoloy. The rods have outside diameters between 1.36 and 1.48 in. (Incoloy-clad rods have 0.54 in. outside diameter and are bundled in 4 x 4 arrays). Fuel rod lengths vary between 28.3 and 45.0 in. These structural differences, along with differences in fissile material enrichment make for a large variety of fuel rods that are included under the general label FRR TRIGA. These fuel types are discussed in greater detail in Addendum F to this SAR.[8]

2.9 Materials Test Reactor (MTR) Canal Fuel

The safety analysis for MTR Canal fuel is in addendum H to PSD 4.12.[9] The fuel is primarily UO_2 of various enrichments. It consists of fuel rods, rod sections, multi-rod test trains, and loose pellets and metallography mounts. Much of the fuel is impregnated with organic potting compounds (epoxy and bakelite). The fuel units are contained in cans, which will be de-watered in the Fuel Canning Station prior to storage in the IFSF storage area.

2.10 References

1. PSD, WIN-107-5.5, "Rover Fuels Processing Facility Final Safety Analysis Report."
2. Lockheed Martin Idaho Technologies, ICPP Fuel Receipt Criteria, Part A for Rover UBM, July 15, 1996.
3. G. L. Huestis, letter to J. M. Mines, "Review of Statements Regarding Log Sheet Summary Listings and Rover Cell 3/4 Storage Inventory," GMH-0-97, March 6, 1997.
4. G. M. Huestis, "UBM Tracking Record Spreadsheet," June 4, 1997.
5. Lockheed Idaho Technologies Company, Fuel Movement Plan for Transfer of Rover Uranium Bearing Material to IFSF, Rev. 0, May 21 1996.
6. PSD 5.5A, "Rover Fuels Processing Facility Rover Deactivation Project."
7. GA Technologies, *Characterization of TRIGA Fuel,* GA Project 3442, October 1986.
8. PSD 4.12F, "CPP-603 IFSF Foreign Research Reactor TRIGA Fuel Handling and Storage."
9. PSD 4.12H, "IFSF Handling and Storage of Materials Test Reactor (MTR) Canal Fuel," Current issue.

3. FACILITY

CONTENTS

FIGURES

3. FACILITY

3.1 Site Description

The INTEC is located at the INEEL. The INTEC is a 147-acre facility, most of which is enclosed by a chain-link perimeter fence. As shown in Figure 3-1, the IFSF is part of a fuel storage complex located in the southwest corner of the INTEC. The CPP-603 storage complex consists of three interconnected fuel storage basins (FSB), a fuel receiving area, and the IFSF. The storage complex is served by truck transportation.

A more detailed discussion of INEEL site characteristics is found in Chapter 1, "Site Characteristics," of Part I, "General Safety Analysis," of the Idaho Nuclear Technology and Engineering Center Safety Analysis Report (INTEC SAR).[1] The discussion covers meteorology, hydrology, seismology, geology, volcanism, population distribution, land and water use, and associated site activities as they relate to the INEEL and the INTEC. Because the IFSF is part of the INTEC, events affecting the INTEC apply to the IFSF.

3.2 Building Design

The IFSF (Figures 3-2 and 3-3) was designed to (1) meet interim fuel storage requirements pending eventual retrieval for final disposal, (2) provide safe storage for fuels that are potentially chemically reactive with water or industrially hazardous when exposed to the environment, and (3) make maximum use of existing equipment and facilities. The IFSF was built as an extension to the CPP-603 Underwater Fuel Storage Facility. Therefore, the CPP-603 cask receiving area 60-ton crane, CRN-SF-001; the CPP-603 liquid waste handling system; and the existing utilities system for CPP-603 are used at the IFSF. Construction of the IFSF was completed in December of 1974.

Design criteria for the IFSF were prepared by Idaho Nuclear Corporation, the INTEC operating contractor at that time.[2] Specific functional requirements included the following capabilities:

1. Receiving and handling Fort St. Vrain, Peach Bottom, and Rover fuel shipments in casks weighing up to 38 tons.

2. Remotely preparing fuel elements for storage, transfer, and processing.

3. Storing 1962 Fort St. Vrain and 804 Peach Bottom fuel elements and 200 containers of Rover fuel.

4. Adequately cooling the stored fuel.

5. Decontaminating the shipping casks.

6. Protecting personnel and the environment from excessive radiation and contamination.

7. Meeting seismic and tornado requirements.

8. Maintaining a dry environment for fuel storage.

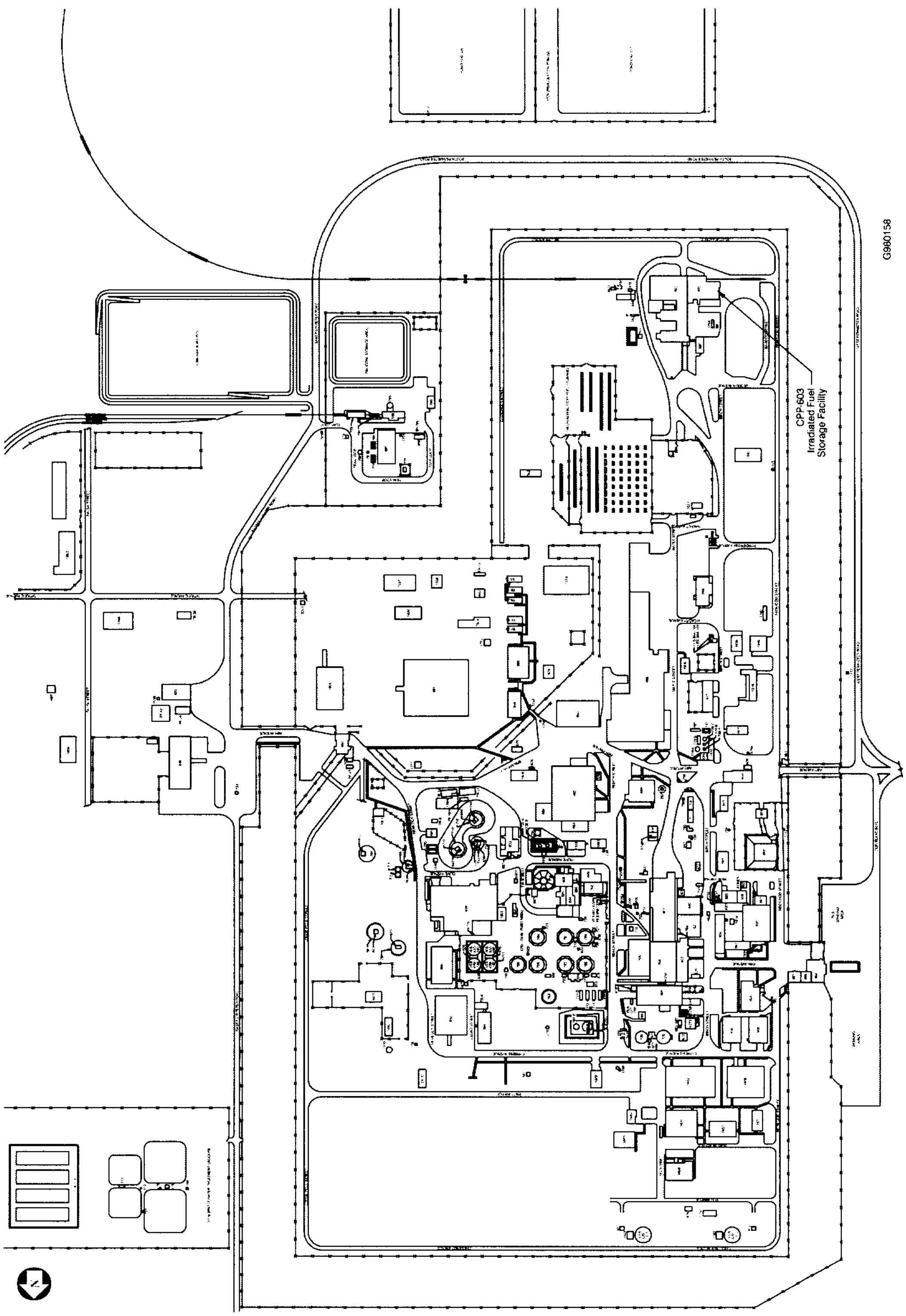

Figure 3-1. INTEC facility map.

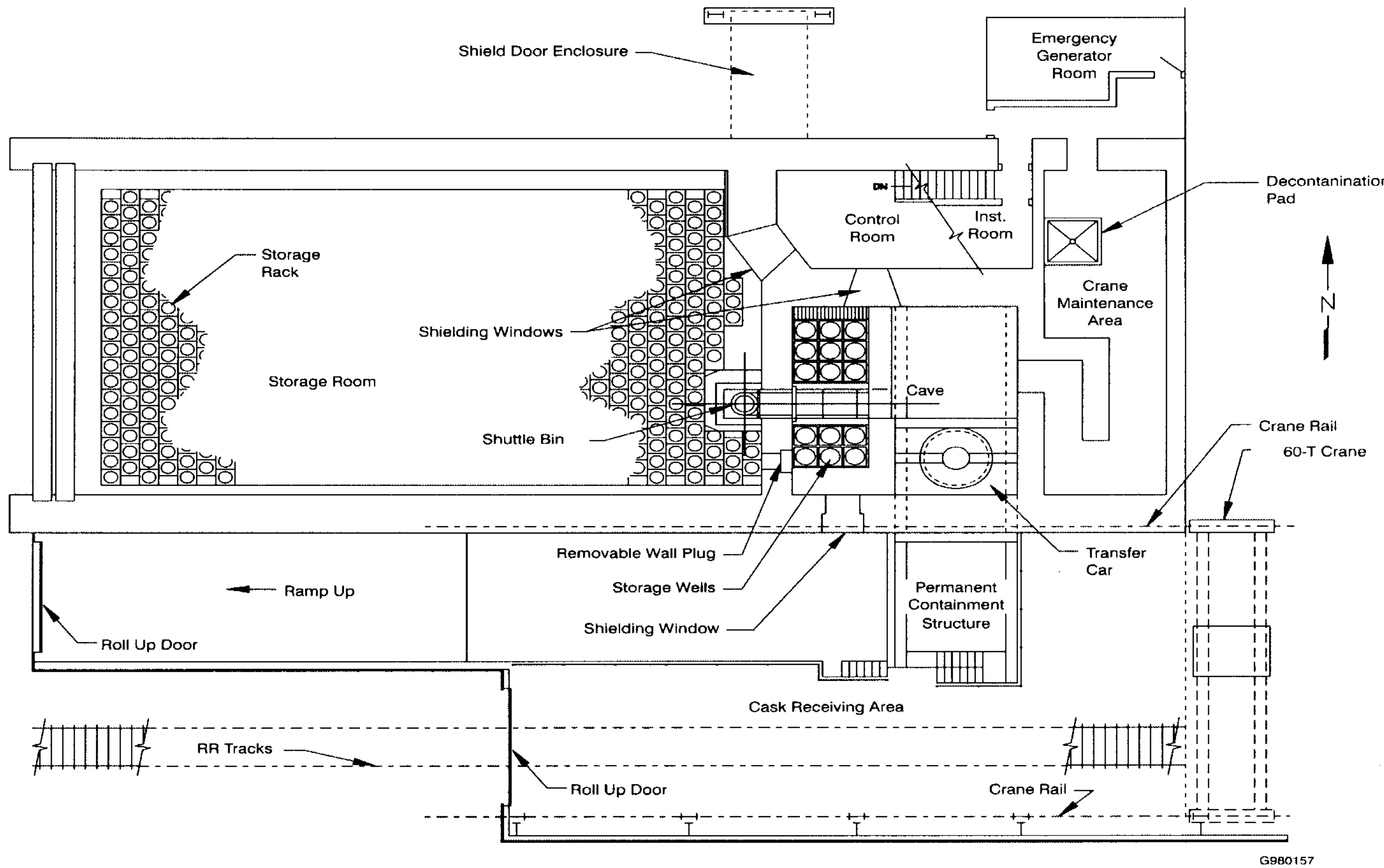

Figure 3-2. Irradiated fuel storage facility plan view.

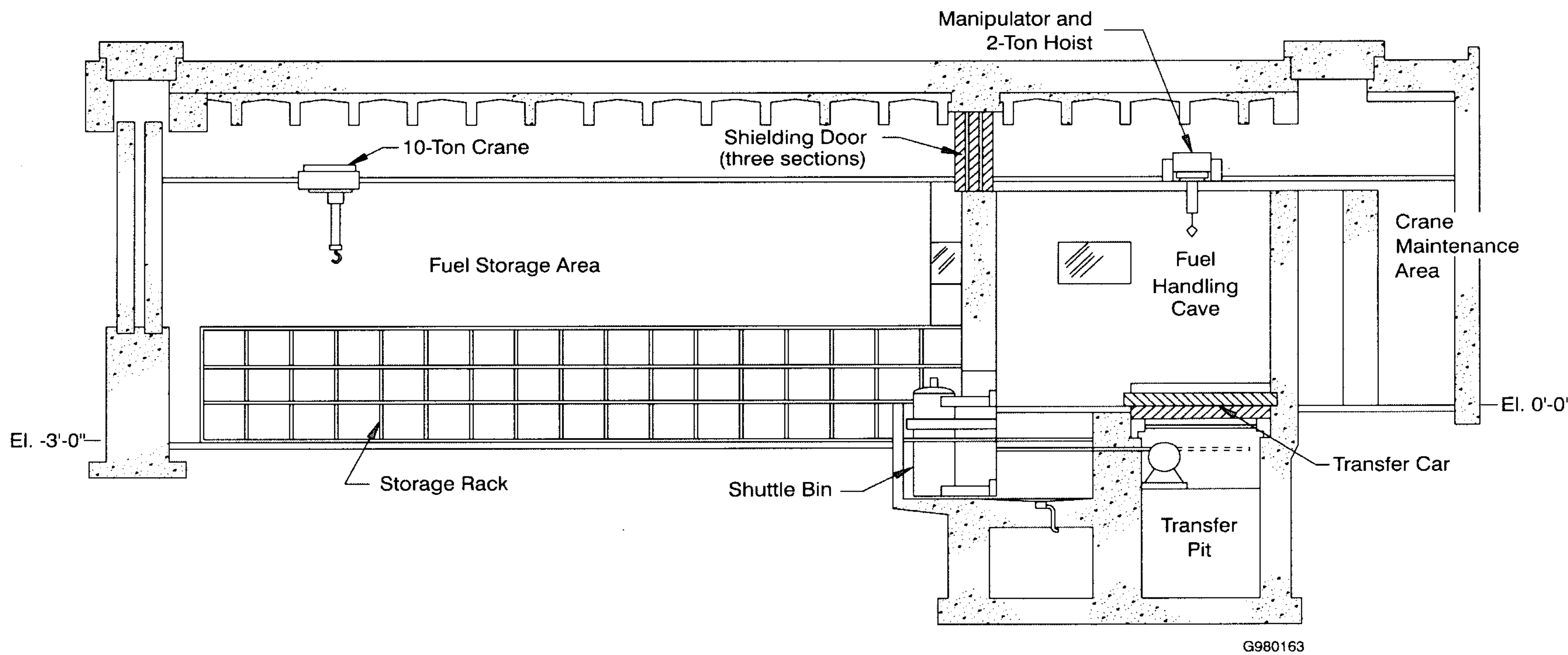

Figure 3-3. Irradiated fuel storage facility section view.

3.3 Building Descriptions

The IFSF is constructed of noncombustible materials, mostly concrete and steel. Concrete shielding walls divide the building into a number of functional areas, each designed and equipped for a specific task. The functional areas include (1) the cask receiving area, (2) the permanent containment structure (PCS), (3) the fuel handling cave, (4) the control and instrument room, (5) the fuel storage area, and (6) the crane maintenance area. The location of each is shown in the description provided below.

3.3.1 Cask Receiving Area

The primary functions performed in the cask receiving area are (1) receiving loaded fuel shipping casks from various reactor or storage locations and (2) transferring fuel from storage to another facility.

The cask receiving area is a 70-ft extension of the west end of the existing CPP-603 cask receiving area. The 60-ton crane, CRN-SF-001, serves both the CPP-603 FSB and cask receiving area and the IFSF cask receiving area. The 15-ton crane, CRN-SF-035, cannot be used in the IFSF because its trucks have a slightly different spacing and bind on the rails in the IFSF cask receiving area.

In addition to the cranes, the cask receiving area contains a truck ramp, a cask transfer pit, and a cask transfer car, all used in unloading fuel transfer casks. The truck ramp lies parallel to the railroad tracks and extends approximately 5 ft belowgrade.

The cask transfer pit, which contains the cask transfer car (see Subsection 4.6), is approximately 10 ft wide, 44 ft long, and 18 ft deep. Approximately one-half the pit is in the cask receiving area; the other half is in the fuel handling cave. A liquid-waste sump is located in the bottom of the cask transfer pit (in the cask receiving area side). Floor drains in the storage area and the fuel handling cave wells are connected to this sump. There is a manual block valve on each drain line as shown in Figure 3-4. These valves are kept locked open to avoid buildup of water in the fuel storage and handling areas should any water leak into the storage facility. The sump is equipped with an automatic pump-out capability. The liquid is pumped to the CPP-603 process waste system for collection and eventual disposal. An indicator light on the outside of the south wall of the fuel handling cave in the cask receiving area shows when pumpout is in progress.

3.3.2 Permanent Containment Structure

The PCS is a hardwalled structure in the cask receiving area that encloses the transfer car and the portion of the transfer car pit outside the handling cave. The PCS provides containment of possible contamination, which could be transferred out from the cave. The PCS has top and side panels, which can open to provide crane access and allow cask transfers. When the cask is positioned in the transfer car, the crane is disconnected and removed, and the PCS is closed. When brought out of the handling cave, the cask can be surveyed and, if necessary, decontaminated before exposing it to the clean environment of the cask receiving area. The PCS has a separate high-efficiency particulate air (HEPA) filtered exhaust system, which exhausts into the cask receiving area. Windows are provided on three sides of the PCS to allow observation of cask handling and decontamination operations. The PCS is furnished with a continuous air monitor (CAM) and radiation area monitors (RAMs), and is covered by the criticality alarm system (CAS) receiving area detector head.

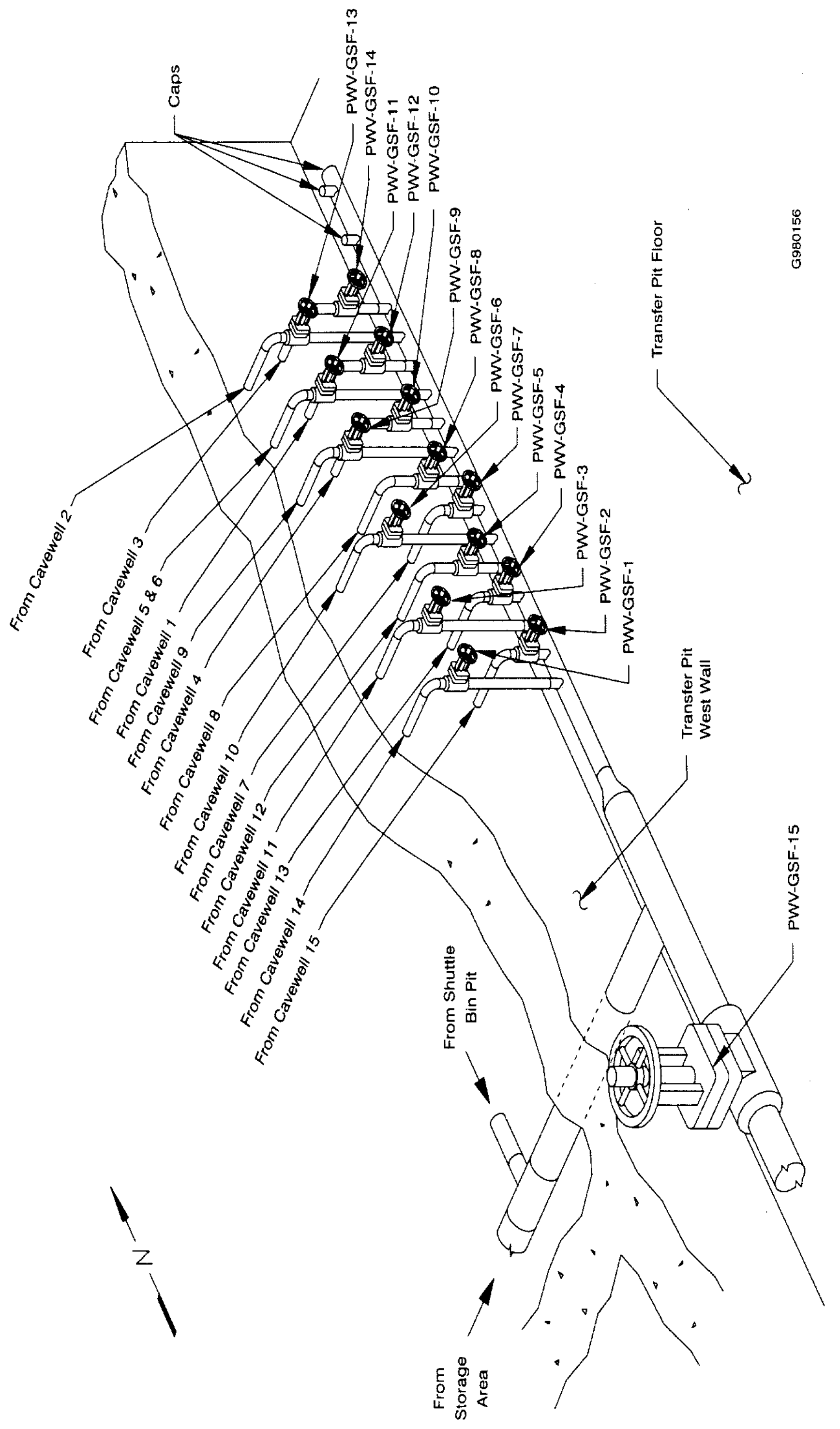

Figure 3-4. IFSF drains.

3.3.3 Fuel Handling Cave

Several functions are performed in the fuel handling cave, including receiving fuel in casks moved in on the transfer car, transferring fuel from shipping casks to storage canisters, preparing fuel elements for storage, operations performed in the Fuel Canning Station, and transferring fuel from storage to shipping cask for transfer to another facility. The remote handling capabilities in the fuel handling cave are also used for miscellaneous operations such as transferring flux wires from one cask to another. Also, miscellaneous fissile material containing a total of 350 g of ^{235}U or less is handled in the cave.

The fuel handling cave is equipped with manipulators, a crane, and a hoist for fuel handling; floor wells for temporarily storing fuel storage canisters; and a shuttle bin for transferring canisters between the fuel handling cave and the fuel storage area (for a description of the storage canisters, see Section 4). In addition, the cave is equipped with the cask transfer car for transferring casks between the cave and the cask receiving area (south truck bay).

Fifteen carbon steel floor wells are provided in the fuel handling cave for convenience in handling fuel shipping and storage baskets and containers. Two of the wells were sized for Peach Bottom fuel shipping baskets: these are 26 in. in diameter and approximately 13 ft deep. One of these wells is used for the Fuel Canning Station. Two wells were sized for Fort St. Vrain fuel. These wells are 20.5 in. in diameter and approximately 16 ft deep. The remaining 11 wells were sized for the IFSF storage canister. These wells are 20.5 in. in diameter and approximately 13 ft deep. If smaller containers are placed in the wells, adapter sleeves are used to reduce the clearance in the wells. When not in use, the floor wells are covered with removable steel cover plates. A 1-in.-diameter drainline connects each floor well to a 2-in.-diameter common header that discharges to the cask transfer pit sump.

To facilitate decontamination and cleanup of the fuel handling cave, the cave floor (except that portion covering part of the cask transfer pit) and the lower 6 in. of the cave walls are lined with stainless steel. The portion of the cave floor that extends over the cask transfer pit must provide shielding between the cave and the pit when the transfer car is in the receiving area and must also support the cask lids when they are removed from the casks. Therefore, this part of the cave floor is a 12-in.-thick carbon steel plate.

Because of the possibility of a criticality or a chemical reaction between water and carbides and the resultant release of fission products from the carbide fuel particles, there are no water supply lines in the handling cave. Further, water is not permitted in the cave while graphite fuel is present. Water is introduced into the cave during the transfer of some fuels to the Fuel Canning Station, when it is left on the fuel elements after drip-drying and in the containers. Some fuel types are brought from wet storage in containers that could retain significant amounts of water. Drip pans are used to collect water that might drip from fuel or its container on the path between the cask transfer car and the Fuel Canning Station. All visible water resulting from these transfers must be removed from the cave before any additional fuel may be brought into the cave. If water (other than that contained in dampened rags, mop heads, etc.) is necessary for decontamination or testing drains in the cave, the fuel inventory must be reduced to 350 g of ^{235}U or less.

A shielded window, coupled with mirrors and video cameras, permits control room viewing of handling cave activities. A labyrinth connects the cave to the crane maintenance area to permit equipment removal and replacement. Also, a shielding window and two remote manipulators are located in the south wall. These provide fuel handling capabilities and are used in Fuel Canning Station operations.

3.3.4 Control and Instrument Room

Fuel handling operations, including transferring and decanning, are performed remotely from the control room. Also, the remote manipulator on the south wall of the fuel handling cave can be used. The 10-ton crane, bridge mounted PaR manipulator, fuel-shuttle bin, and cask transfer car, as well as the closed circuit television, heating and ventilating, communication, and lighting systems, are all operated and controlled from the control room.

The control room is an integral part of the fuel storage facility. Because the 10-ton storage facility crane must have access to all regions of the facility, the crane must pass over the control room. To permit crane access and still provide radiation protection to operating personnel, the control room has its own shielding roof. To aid the facility operators in viewing the fuel, the control room floor is located about 8 ft above the storage area floor.

Two shielding windows and television monitors are provided in the control room to permit viewing the handling cave and fuel storage area operations: one window overlooks the fuel handling cave, the other the fuel storage area (see Subsection 4.8). A television (TV) camera can be mounted on the trolley of the 10-ton crane to provide continuous surveillance of the area in which the crane is operating, especially the point at which the crane hook engages a storage canister lifting bail. A TV camera can also be mounted on the remote-controlled PaR manipulator. A third TV camera is mounted on the mezzanine wall to monitor swing rail operations. Its associated monitor is in the control room (for further discussion of the TV systems, see Subsection 4.3.2). Areas of the facility that cannot be viewed directly through the shielding windows or indirectly with the TV system are observed with mirrors.

A concrete floor divides the control room into two levels, an upper level control room and a lower level instrument room. Within these areas are the controls and circuitry for the storage facility's equipment and systems including (1) the 10-ton crane, (2) the PaR manipulator and hoist, (3) the cask transfer car, (4) the movable shielding door, (5) the fuel-shuttle bin, (6) the heating and ventilating system, (7) the cave swing rail, (8) the viewing window shield, and (9) the Fuel Canning Station.

3.3.5 Fuel Storage Area

The fuel storage area contains the carbon steel storage rack that provides both spacing and support for the 636 fuel storage canisters, each of which is 18 in. in diameter and 11 ft long. The storage rack maintains the canisters in a staggered 24-in. center-to-center spacing for criticality control and heat transfer purposes. The rack has 38 rows of canisters, alternating 17 and 18 canisters per row. For heat transfer reasons, the storage rack also positions the canisters about 2-1/2 in. above the facility floor. The storage rack and canister are shown in Figure 3-5.

The top of the storage rack, except for the openings for the canisters, is covered with sheet metal, which allows the rack to serve as a plenum for cooling air in addition to providing canister positioning and support. Most of the cooling air is supplied at one end of the rack structure and is exhausted at the other end to provide positive cooling of the stored canisters. The main airflow is from the supply plenum at the west end of the rack to the exhaust plenum at the east end of the rack. Both plenums are beneath the rack; therefore, the major flow path is below the surface. Thus, if canisters are removed from the rack, leaving openings, the majority of the airflow would still be below the rack to ensure canister cooling. A small flow of air is directed above the rack to prevent dead air spaces and hot spots. The storage canisters have lids to limit cooling air contact with the stored fuel. The storage rack cooling system is illustrated in Figure 3-6.

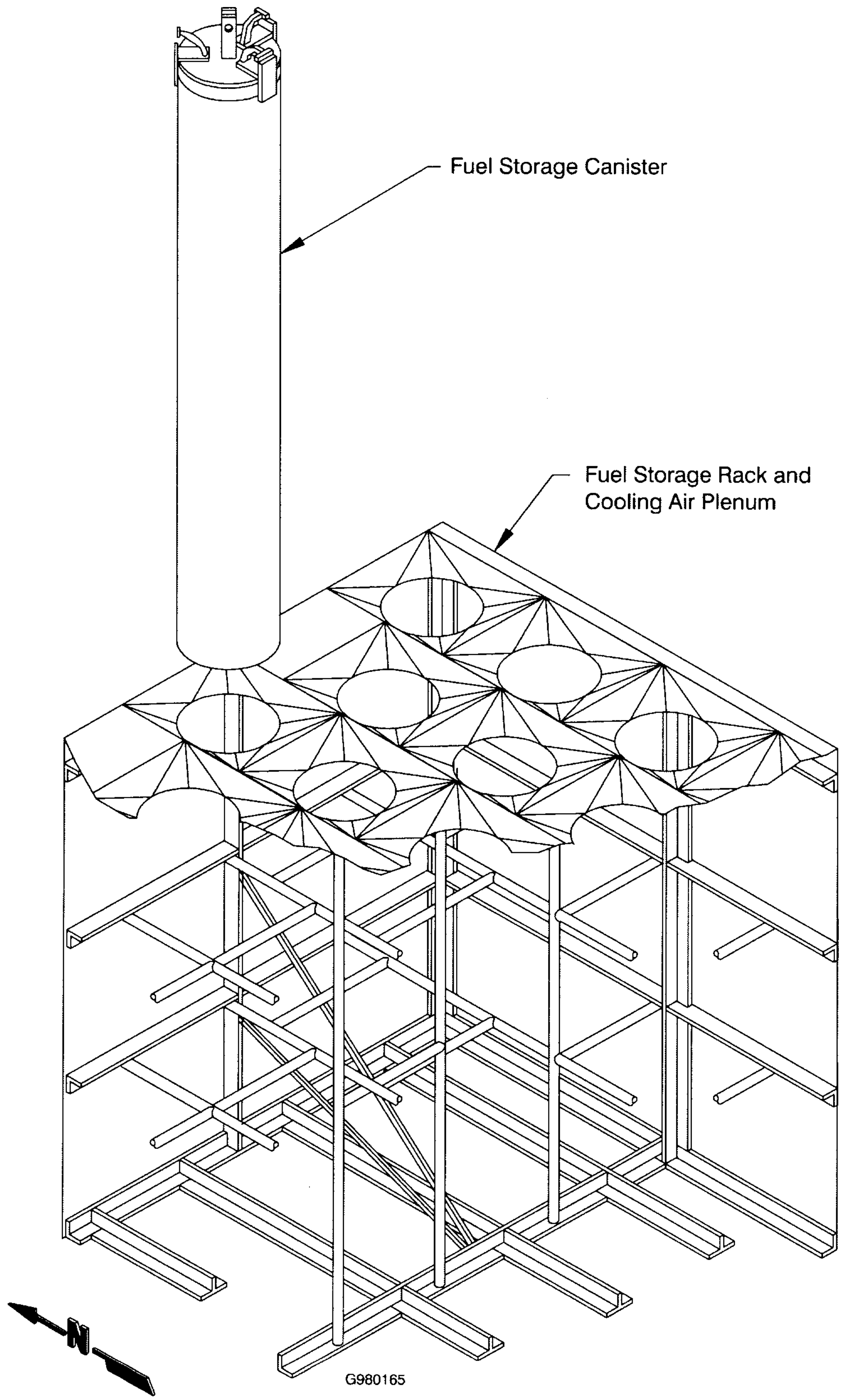

Figure 3-5. Fuel storage rack and canister.

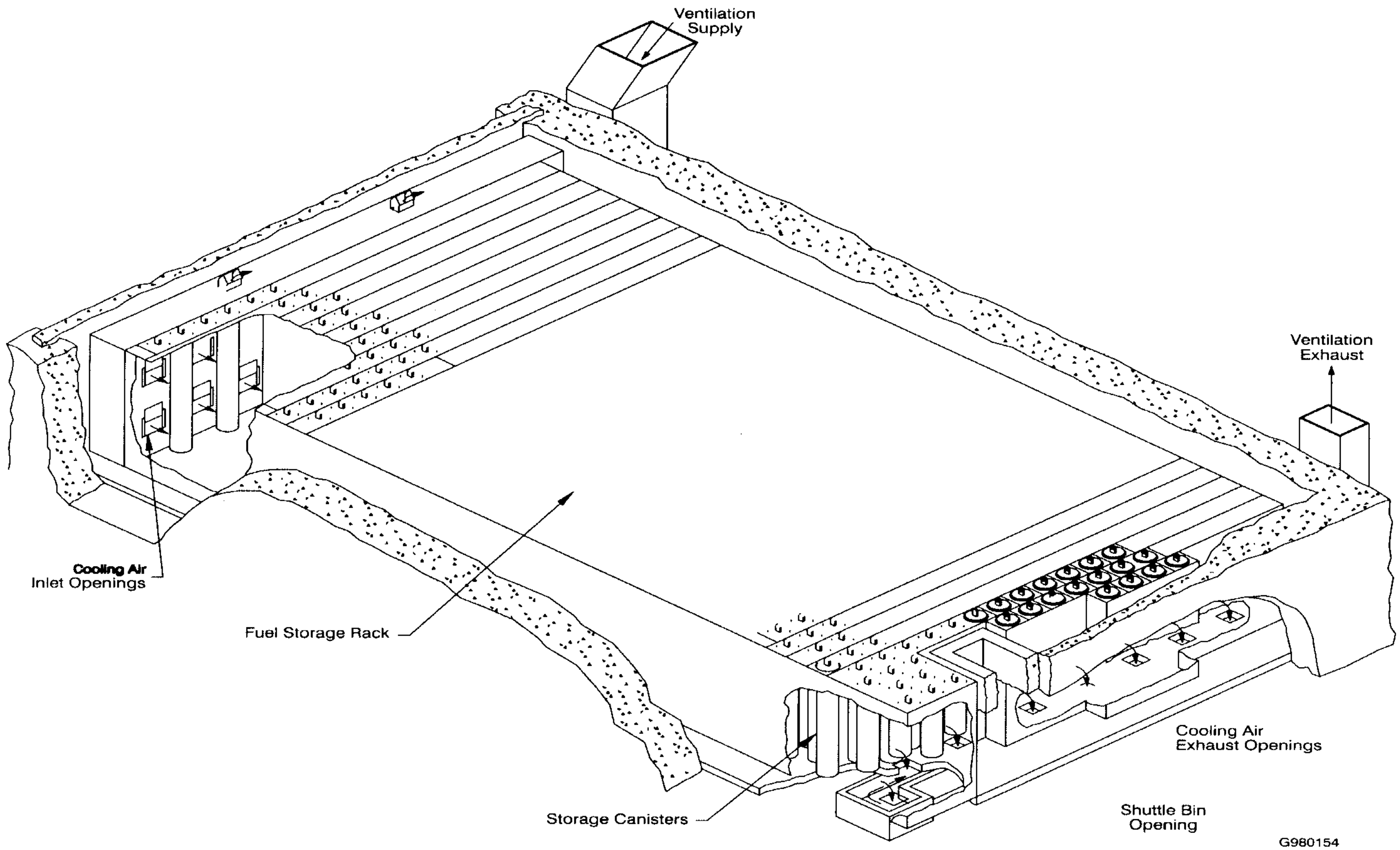

Figure 3-6. Fuel storage area isometric.

As in the fuel handling cave, water and water lines are excluded from the storage area to prevent the possibility of either a fuel-water reaction or one of nuclear moderation. Floor drains are provided to drain any water from the storage area to the transfer car pit.

Canisters containing fuels being processed in the Fuel Canning Station can contain significant amounts of water prior to drying. If a canning station malfunction should occur when a canister is in the canning station, a personnel entry into the handling cave might be necessary. It might be necessary to remove the canister, prior to drying, from the canning station, place it into the shuttle bin, and move the shuttle bin to the storage area side of the shield wall. Controls are provided to prevent the potential intrusion of water from such a canister into the fuel storage array.

3.3.6 Crane Maintenance Area

The crane maintenance area, which is approximately 13 ft wide and extends the entire width of the east end of the fuel storage facility, is a controlled-access area. However, the area design permits remotely operated equipment (TV camera, PaR manipulator, etc.) to be moved into the area for contact maintenance. A labyrinth connects the crane maintenance area to the handling cave, permitting passage of equipment between both areas while maintaining shielding integrity.

3.3.7 West Wall Modification

The upper 18 ft of the west end of the fuel storage area was originally fabricated in removable sections to allow for future expansion of the facility. Seismic analysis performed in 1996 and 1997 indicated that this design introduced structural deficiencies that could be removed by constructing a new full-height, solid west wall (see Subsection 8.1.1.). This modification was constructed in 1997. The new west wall is connected to the extensions of the north and south walls that projected beyond the original west wall, and to the roof by a concrete cap that bridges the original west wall.

3.4 References

1. Lockheed Martin Idaho Technologies Company, Idaho Nuclear Technology and Engineering Center Safety Analysis Report, INEL-94/022, Part I, "General Safety Analysis," Chapter 1, "Site Characteristics

2. G. E. Bingham, R. D. Modrow, and R. S. P'Pool, *Design Criteria for the HTGR Fuel Storage Facility*, Idaho Nuclear Corporation, CI-1214, March 1971.

4. EQUIPMENT

CONTENTS

FIGURES

TABLE

4. EQUIPMENT

A considerable amount of equipment is available in the fuel storage facility to enable the irradiated fuels to be safely and efficiently handled and stored. A brief description of the major pieces of equipment and their functions is presented below.

For some equipment items described in this section, a minimum design lifetime (e.g., in terms of operating cycles) was originally specified. For those items with potentially significant safety consequences if they fail, a preventive maintenance program is in place to prevent untimely failures and extend the equipment life as much as possible. Thus, many of these items have operated, and are expected to continue to operate, well beyond their design lifetime.

4.1 Storage Canisters, Inserts, Pedestals, And Buckets

Carbon steel or stainless steel storage canisters are used for storing the fuels in the IFSF. Fuels to be processed in the Fuel Canning Station use stainless steel canisters. Specialized equipment is necessary for handling and placing the fuel elements within the canisters. The Rover UBM is stored in a SS canister that has essentially the same body design as that used for the canning station fuels, except that it is fabricated from thinner SS. A new water-shedding lid design is used for Rover UBM SS canisters. All canisters are designed to the same outer dimensions for compatibility with storage racks and cave floor wells and equipment, and for consistency with seismic and other analyses. To establish consistent terminology, the terms used throughout this document include the following:

1. Carbon steel storage canister (CAN-GSF-101) - An 18-in.-diameter by 11-ft-long carbon steel container that is used to store intact or broken fuel elements, or sealed aluminum cans or cardboard tubes containing fuel. The carbon steel canister lid restricts water entry.[1]

2. Stainless steel storage canister (448646-2 marked on upper flange of canister, port position number only marked on canister lid) - The same size as the carbon steel storage canister, but with a different lid design. The canister was originally designed for fuel processed in the Fuel Canning Station.[2]

3. Light weight SS storage canister (CAN-GSF-276, marked on can body and on lid) - The same canister dimensions as the previous SS storage canister, but fabricated from a thinner, lighter weight SS and with a different lid design to shed water.

4. Canister insert - A 16-in.-diameter carbon steel container that fits inside a storage canister and holds fuel elements or sealed aluminum cans. Canister inserts may be stacked to form two tiers.[3]

5. Pedestal - A carbon steel frame made of two half-sections of 20-in.-diameter pipe set side by side on a base. It is used to position canister inserts at a 60-degree angle from horizontal for ease of loading.

6. Buckets - For canning station fuels, stainless steel inserts that are designed to hold specific fuels during transfer to and processing in the Fuel Canning Station, and subsequent storage in the canisters. Rover UBM cans are also transferred and stored in buckets within the IFSF. The Rover UBM buckets are made of aluminum in order to maximize the amount of Rover UBM a canister may hold, while still meeting the 2000 lb maximum loaded canister weight

allowed for rack storage. Because the canned Rover UBM will continue to be stored in a dry environment, galvanic corrosion of the aluminum buckets is not a concern. The specific buckets and approved fuel types include the following:

BU-GSF-ATR6	six ATR fuel elements
BU-GSF-ATR8	eight ATR fuel elements
BU-GSF-ORR	six ORR fuel elements
BU-GSF-MURR4	four MURR fuel elements
BU-GSF-MURR6	six MURR fuel elements
BU-GSF-HFBR	six HFBR fuel elements
BU-GSF-TRIGA	three TRIGA cans
BU-GSF-WAPD	three WAPD cans
BU-GSF-ARMF	five ARMF and CFRMF fuel elements
BU-SF-911	six ROVER UBM cans

NOTE: For the aluminum plate fuels (ATR, MURR, ORR, and HFBR), the fuel plates/pieces from one splayed element are packaged in the Fuel Storage Basin (FSB) and placed in one or more compartments of the same bucket. No plate/piece is placed in a bucket compartment with an intact element. Both the intact and splayed elements received from the FSB are already packaged in the buckets. No packaging of splayed and intact elements is anticipated in the IFSF dry side. If fuel has spilled out of the bucket or canister during an accident and is splayed, a separate recovery plan will have to be developed and approved. A splayed element results from failure of the swaged joints attaching the fuel plates to the nonfuel side plates. Failure of these joints means that some or all of the fuel plates are no longer attached to the side plate. A fully splayed element means that all of the fuel plates have separated from the side plates. Aluminum plate fuels are expected to remain intact during routine fuel handling operations and during a design basis seismic event.[4]

7. Cardboard tubes - A tube that has a 2-in. or 2.75-in. outside diameter, with approximately a 0.09-in. wall thickness, and is 52 in. or 53.75 in. long. The ends are closed with 0.75-in.-thick plugs.

8. Metal Rover fuel tube - A tube that has a 2.125-in. outside diameter, a 0.035-in.wall thickness, and is approximately 56 in. long. One end is welded closed with a metal plug, and the other end is closed with a removable metal and rubber plug.

9. MTR Canal fuel cans - CAN-GSF-105, -106, and –107. These are stainless steel cans made from 5 in. schedule 10 pipe (a fourth can type, CAN-GSF-108 is made from 7.5 in. diameter,

10. 0.120 wall stainless steel tubing) with drain holes and a lid that can be tightened to prevent spillage of the contents.

The storage canisters are 11 ft long and 18 in. in diameter. The carbon steel canisters have lids that reduce air exchange and particulate leakage. The lids have lifting bails to permit remote handling with the crane or the manipulator. A metal identification tag having 2-in.-high letters and numbers is attached to each lid. Each tag identifies a specific storage rack position and provides a means of specifying the location of stored materials. The canister bottoms are watertight.

Stainless steel canisters are used for storing fuels processed in the Fuel Canning Station and may be used for storing other fuels as well. The canning station fuels are held in buckets unique to the fuel type, with one or more fuel types in a single canister. These SS canisters (with the drawing number 448646-2 marked on the upper flange of the canister) were originally designed for use in the fuel canning station. (See Addendum B for further discussion.) These canisters have lids designed (1) for compatibility with the Fuel Canning Station as well as with standard IFSF equipment, and (2) to allow venting. The storage lids (only port position number marked) for the canning station canister are not capable of shedding water that might drip onto them. Therefore, these canisters may not be used for storing fuels for which water exclusion is required for criticality controls. These stainless steel canisters are depicted in the canning station in Addendum B to the SAR. The SS canisters replace the original carbon steel canisters (CAN-GSF-101) in the storage area rack ports in which they are used and are numbered according to storage rack position.

A lighter-weight SS canister steel (CAN-GSF-276) was designed to be used for Rover UBM and future fuels in order to maximize fuel stored in each canister. A new, water-shedding lid was designed for this lighter SS canister. This lid must be used for Rover UBM for criticality prevention. The lighter SS canister and water-shedding lid are intended to be used for other future fuels as well. This canister and its water-shedding lid are depicted in Figure 4-1.

4.2 Fuel-Shuttle Bin

Direct transfer of fuel canisters between the fuel handling cave and the fuel storage area is not possible because of the shielding wall between these two areas. Therefore, fuel canisters are transferred between the two areas by means of a fuel-shuttle bin (Figures 3-1 and 3-2). The shuttle bin is a remotely controlled, electrically driven container mounted on wheels. The bin can accept a cylinder up to 31 in. in diameter and 13 ft long. An adapter plate reduces the container diameter to 18-1/2 in. to fit the storage canisters. The shuttle bin operates on rails installed in the shuttle bin pit that extend beneath the shielding wall separating the cave and the fuel storage area. The shuttle bin handles a loaded canister weighing 2000 lb. The 2000-lb weight restriction is driven by storage rack analysis assumptions. Analysis shows that the shuttle bin itself can handle a load up to 3000 lb.[5]

The pit also functions as a labyrinth for radiation protection. The shuttle bin can be positioned in the fuel storage area or the handling cave. The facility crane, CRN-GSF-101, or the PaR manipulator hoist, CRN-GSF-401, can be used to insert or remove fuel storage canisters. A 6-in.-thick lead plate, encased with carbon steel, which moves with the shuttle bin, is located on the handling cave side of the bin to provide shielding between the fuel storage area and the handling cave. When the bin is positioned in the fuel storage area, the lead plate completely closes the hole in the shielding wall to reduce the radiation field in the handling cave.

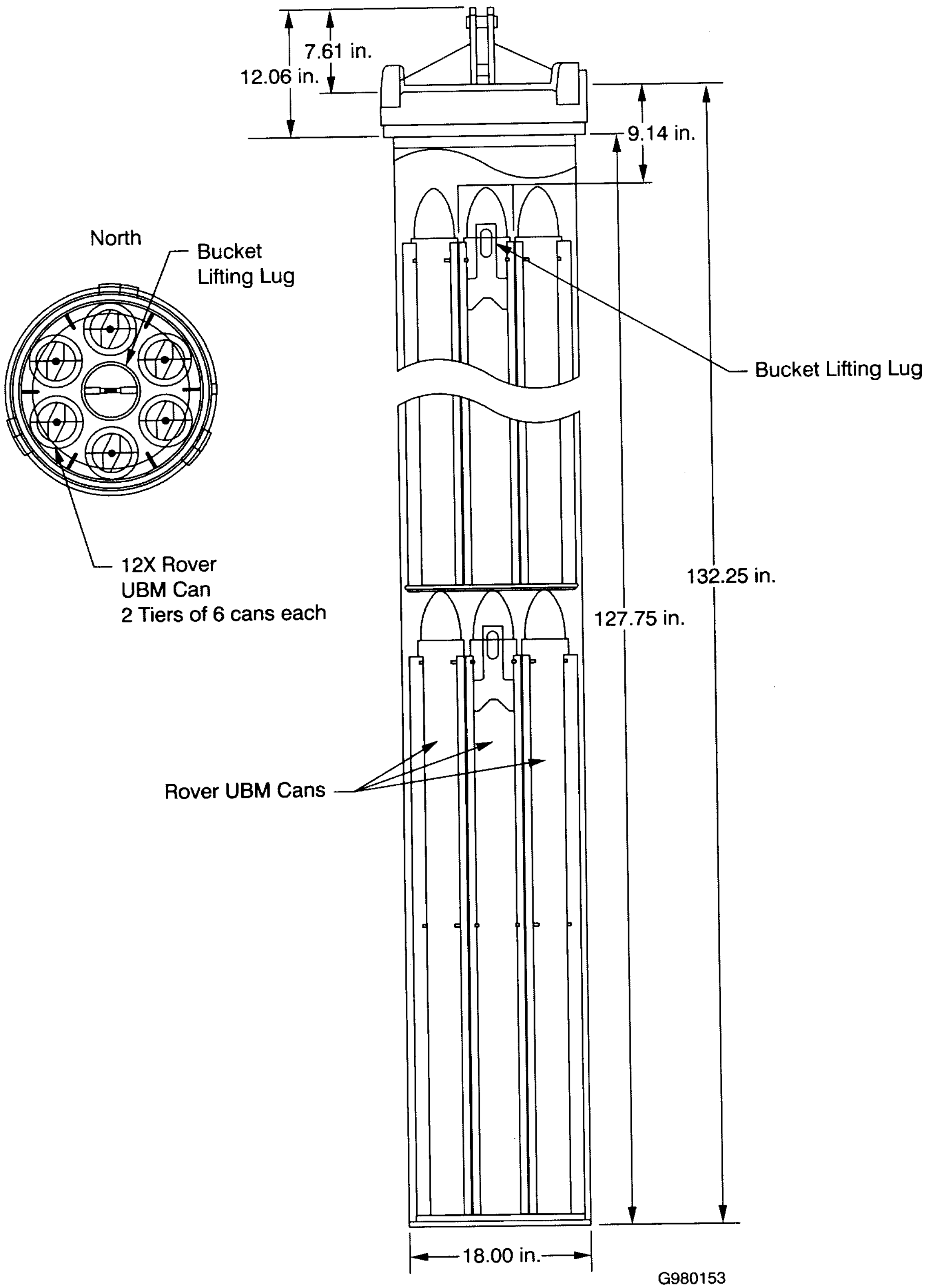

Figure 4-1. Rover UBM canister.

The shuttle bin is remotely controlled from the control room where both movement-indicating and position-indicating lights are provided. The control panel includes two start buttons, one to move the bin into the fuel storage area, the other to move the bin into the fuel handling cave; a stop button; a lockout key switch; a key-operated travel limit switch bypass; and blue position indicator lights for both the transfer car and the shuttle bin. Limit switches prevent bin overtravel. The key-operated lockout switch prevents inadvertent or unauthorized operation of the bin. The limit switch bypass permits the bin to be moved farther than normal into the fuel handling cave for maintenance purposes. The shuttle bin is provided with normal power only.

For maintenance and to avoid potential direct radiation problems, the shuttle bin drive system is located in the cask transfer pit. In addition to the electrically driven motor, the shuttle bin drive system is also provided with a hand wheel for manual positioning, should the drive motor fail. Any time the shuttle bin is to be removed from its pit, the lead shielding plate on the end of the shuttle bin is first removed and suspended from wall brackets so that the plate covers the hole through the shielding wall and maintains the radiation environment in the handling cave at an acceptably low level. The shielding plate is handled remotely.

A drain line connects the bottom of the shuttle bin pit and each individual handling cave well to the cask transfer pit sump, should decontamination of the handling cave wells and the shuttle bin pit become necessary. A manual block valve located in the cask transfer pit is kept locked open to avoid buildup of water should any water leak into the storage facility.

4.3 Cranes

Two cranes and a hoist are available for use at the IFSF: CRN-SF-001, currently rated for 60 tons in the cask receiving area, and CRN-GSF-101, currently rated for 10 tons in the fuel handling cave and 3-1/2 tons over the mezzanine and in the fuel storage area in the fuel storage facility. Each crane is provided with an electrical solenoid and a mechanical brake so that in the event of power loss, the crane hoist locks up and the load is not dropped. A 2-ton capacity hoist, CRN-GSF-401, is located on the bridge mounted PaR manipulator. CRN-GSF-401 is always east of CRN-GSF-101. If CRN-GSF-101 were to fail in the storage area, hoist CRN-GSF-401 could be used to attach a winch cable to CRN-GSF-101, which could be used to winch the disabled crane back to the handling cave.

4.3.1 CPP-603 Cask Receiving Area Crane

The 60-ton crane, CRN-SF-001, serves the CPP-603 cask receiving area. The rails for the 60-ton crane have been extended into the IFSF cask receiving area to allow the crane to be used in both the CPP-603 and IFSF cask receiving areas to transfer shipping casks between a transport vehicle and the fuel unloading areas.

The 60-ton crane is a Judson-Pacific crane with a trolley travel of approximately 27 ft and a maximum hook height of 24 ft. The crane can travel the entire length from the basin area to the IFSF cask receiving area. The control pendant attached to the crane controls the crane, which is supplied with normal power only.

4.3.2 Fuel Storage Facility Crane

The 10-ton bridge crane, CRN-GSF-101, is used in the fuel storage facility to remove and replace cask lids; load and unload fuel from the casks; and transfer fuel, canisters, and equipment within the storage facility (see Figure 6).

Power to CRN-GSF-101 is provided through either of two control cables, one attached to each end of the bridge. The primary control cable provides power for complete crane operation. The secondary control cable provides power to the bridge and hoist drives only. The system used is selected by a switch located on the crane power center door. The crane is provided with both normal and standby electrical power.

The crane may be controlled from either the control room station or from a control pendant in the crane maintenance area. Both stations permit complete operation of the crane. However, through an interlock, the controlling station is selected from the crane maintenance area control pendant. If the crane maintenance area controller is unplugged, a dummy plug must be inserted into the junction box to pass control to the control room unit. Each station is provided with an indicator light to indicate which station has control.

Each control station is provided with a master "Power On" pushbutton and an impact switch that interrupts power to the crane if the control pendant is dropped.

The variable-speed crane hoist, trolley, and bridge movements are independently controlled through finger switches. A switch is provided for each motion, and the direction and distance that a switch is turned determine the direction and speed of the controlled motion. All switches are spring-loaded to return to the "Off" position when they are released.

CRN-GSF-101 is equipped with limit switches that prevent bridge, trolley, and hoist overtravel and with a proximity switch that prevents inadvertent contact between the crane and manipulator bridges. A proximity switch override is provided on each control station, should bridge contact be desired.

Disconnecting the main power to the crane allows the bridge to freewheel and permits bridge retrieval by the crane retrieval system. However, when the bridge clutch is engaged, undesired bridge freewheeling is prevented as long as the main breaker is closed.

The probability of CRN-GSF-101 failing completely while it is located in the fuel storage area of the IFSF facility is low. However, personnel access to this area for any reason is impossible when fuel is present. Therefore, special precautions were taken in the design of the crane to ensure that any probable failure could be corrected. Precautions include a dual drive system for the crane bridge; dual electric-hoist brakes; redundant hoist motor drives; a fail-safe tong-type hook; dual control cables; and standby power.[a] However, the trolley drive motor does not have a backup. The crane is designed to operate in the high-radiation environment of the storage facility. To prevent unnecessary radiation damage, the crane is positioned in the fuel handling cave when not in use. Should a total crane failure occur, the crane bridge could be placed in the free-wheeling mode and the manipulator (Subsection 4.5) could be used to aid in retrieval of the crane. The manipulator can be used to attach cables to each end of the crane bridge. The cables are attached to hand-driven winches, mounted on the wall of the crane maintenance area, which can be used to pull the crane back into the handling cave and crane maintenance area.

The fail-safe tong-type hook on the crane ensures that no load will be disengaged from the hook and dropped in the event that crane power fails. The crane hook consists of two approximately equal sections, one that pivots and one that is stationary. The pivoting section is driven by a dc linear actuator

a. Furthermore, any load being lifted by any of the cranes cannot drop in the event of a power failure because of the presence of an electric solenoid and a mechanical brake. Movement of the load is constrained by these features, which are tested during preventive maintenance.

that closes and opens the hook to engage and disengage items to be lifted. The stationary portion of the hook is pinned in position but will pivot when the release pin is pulled to release the load if crane power is lost with the crane carrying a load. The manipulator, through the use of a long-handled tool, can remove the release pin.

A TV system can be mounted on the crane to provide visual monitoring of fuel canister handling. A TV camera and a quartz iodide light are mounted beneath the crane hoist trolley and are focused at the fuel canister grappling point, located approximately 18 ft beneath the trolley. The narrow angle lens of nonbrowning glass provides a viewing field approximately 2 ft square, thus providing a relatively close-up view of the grappling operation on the control room monitor. Also, the TV system assists in storage canister position identification for rack locations beyond the field of view of the control room shielded window.

4.4 Monorail

A monorail beam with a design capacity of 1000 lb is provided on the roof of the storage facility. The monorail frame is anchored to the roof, and the beam is located approximately 5 ft above the roof of the building near the west end of the facility. The beam is approximately 17 ft long with 5 ft extending beyond the north edge of the roof. The monorail is provided to aid in replacing the equipment located on the facility roof, including blowers, filters, duct, etc.

4.5 Manipulators

Three manipulators are available in the fuel handling cave. The bridge-mounted manipulator was installed when the facility was built. The two remote manipulators located on the south wall were installed in 1985.

4.5.1 Bridge-Mounted PaR Manipulator

A single arm, electrically operated, remotely controlled, bridge-mounted manipulator is provided in the fuel storage facility for performing remote operations that cannot be performed with the crane. The manipulator is mounted on a trolley and bridge similar to those provided for the 10-ton crane, except no redundant systems other than the trolley drive, and power and control cables are provided. The manipulator and a 2-ton hoist mounted on its trolley are designated CRN-GSF-401. The manipulator specifications are shown in Table 4-1.

When remote viewing is required, a TV camera is mounted on the manipulator and a TV monitor is placed in the control room. The manipulator is equipped with a 1000-lb capacity shoulder hook and the 2-ton capacity bridge-mounted hoist. The manipulator's capabilities, which include an arm reach of about 18 ft and wrist, elbow, and shoulder movement, permit retrieval of objects from any part of the floor of the handling cave. The manipulator has a capacity of 300 lb with the hand and arm held straight down and 150 lb with the hand and arm in any other position.

The crane and manipulator bridges operate on the same set of rails but are completely independent, which permits full facility coverage by the manipulator. The manipulator is designed to operate in the storage area environment. However, administrative procedures prohibit using the manipulator in the fuel storage area except in an emergency situation. CRN-GSF-401 is always east of CRN-GSF-101, which could complicate a possible recovery of CRN-GSF 101 if it were to fail while in the storage area.

Table 4-1. Manipulator specifications.

Item	Opening	Speed	Force	Torque	Rotation	Travel	Capacity
Hand	0 to 5 in.	Open-close: 1 to 18 ipm	0 to 200 lb	--	--	--	--
Hook	0 to 6 in.	0.5 to 5 ipm	0 to 800 lb	--	--	--	--
Wrist							
pivot	--	1.2 rpm	--	--	cw/ccw 155/310	--	--
telescope	--	17 ipm	150 lb, push or pull	--	--	4 in. in or out	--
Rotate	--	1 to 7 rpm	--	420 in.-lb	continuous cw/ccw	--	--
Elbow, pivot	--	1.2 rpm	--	--	cw/ccw 135/270	--	--
Shoulder							
rotate	--	3 rpm	--	2000 in.-lb	continuous cw/ccw	--	1000 lb
pivot	--	1.2 rpm	--	--	cw/ccw 125/250	--	--
Hoist	--	8 fpm	--	--	--	40 ft	2-ton
Carriage and bridge	--	1.5 to 15 fpm	--	--	--	--	--
Arm (telescoping tube)	--	Extend-retract 1 to 15 fpm	--	--	--	18 ft	Vertical lift: 300 lb; any other position: 150 lb

The manipulator control system is quite similar to that provided for the crane. Similar features include two color-coded control stations and a dummy plug, a controller selector switch, redundant control cables and carriage drives, travel limit switches and a bridge travel limit override pushbutton, a proximity switch, and spring-loaded switches that regulate the velocity and direction of each manipulator motion in proportion to the direction and amount of switch displacement. In addition, the system contains controls to regulate the gripping force of the manipulator jaws, raise and lower the 2-ton hoist, open and close the hoist grip, and control the speed and direction of the manipulator-operated power tools.

The manipulator is designed to be fail-safe to the extent that all motions hold their full-rated load during a loss of power, and the carriage and bridge are self-locking. Should a manipulator failure occur that necessitates emergency retrieval of the manipulator, a pushbutton in the power control center permits the bridge to freewheel and allows retrieval of the crane and manipulator bridge. The manipulator arm hoist cable is provided with a slack cable limit switch that serves as a lower limit switch and also stops arm movement should any misoperation or malfunction result in a slack cable. The manipulator is provided with standby power.

The manipulator bridge, trolley, and hoist motions are protected against overtravel by limit switches and, where applicable, by mechanical stops. The bridge is also equipped with a proximity switch that, unless bypassed, prevents the bridge from contacting any metal object. All manipulator motors are totally enclosed units, and except for the hoist and hoist grip motors, are variable speed dc motors for highly accurate control.

4.5.2 Remote Manipulator

The remote manipulator is designed to reproduce the natural movements and forces of the human hand. The manipulator motions include elevation, twist, azimuth and Z-motion lock, Y-motion lock, X-motion lock, and electrically driven slave-end lateral rotation, controlled by switches located on the hand grip. Except for slight amounts of deflection and lost motion, the manipulator tong will move as the operator moves the manipulator handle, no matter how complex the motion may be as long as it is within the dimensional limits of the manipulator. The forces at the tong will be equal to those applied by the operator at the handle, except for slight amounts of friction and unbalance. The tong squeeze motion, however, has a mechanical force multiplication to enable the operator to develop a force high enough in the tong squeeze to grasp and manipulate very heavy objects. Except for the tong squeeze force, the operator must exert the same force on the operator arm as on the remote arm.[6,7]

To enable the operator to cover a greater volume in the cell while remaining near the window, the manipulator is equipped with three electrically driven indexing motions (Y and Z, or X, Y, and Z). These indexing motions are counterbalanced to keep the manipulator balanced for ease of operation.

The operator may select the motion desired, or the "Off" position, with the push button mounted within reach of the operator's thumb at the operator handle. A light indicates the motion selected, while the "Off" position has no light. Once the motion has been selected, the manipulator can be indexed by moving the direction switch with the thumb to the right or left for the direction desired, as indicated on the switch plate.

The manipulator is equipped with speed control for the X- and Y-indexing motions. The speed control is set so that the indexing motors are traveling at the desired speed.

The manipulator is capable of handling a load of 100 lb with the tong grips. The manipulator is capable of handling the load at a distance of 8 ft from the hot side of the 4-ft-9-in.-thick wall.

Radiation shielding is incorporated into the manipulator assembly to provide gamma shielding equivalent to 12 in. of lead and neutron shielding equivalent to 4.75 ft of concrete.

The hot-side components are made of materials suitable for decontamination with nitric acid, Turco #4502, and oxalic acid. The tubes are constructed of stainless steel. Boots covering the slave arm prevent migration of contamination out of the handling cave.

The manipulator operates on 120-V, single-phase, 60-hertz power.

4.6 Cask Transfer Car

A specially designed car, located in the cask transfer pit, is used to support the fuel shipping casks and transfer them between the cask receiving area and the fuel handling cave. The car is capable of isolating the fuel handling cave from the cask transfer pit to maintain ventilation control and provide radiation shielding between the fuel handling cave and the cask receiving area. The transfer car, shown in Figure 4-2, consists of a 12-in.-thick steel plate (constructed out of two 6-in.-thick plates pinned together), 12 ft wide and 35 ft long, mounted on three standard railroad trucks. The car operates on 135-lb/ft steel rails located near the top of the cask transfer pit and has an overall travel distance of 14 ft. The transfer car has a 278-ton capacity. The PCS encloses the transfer car pit. Therefore, the car and cask are always enclosed for confinement of radioactive contamination, except when the PCS doors are open.

To accommodate the various casks with a single cask transfer device, the cask transfer car was fabricated with an 8-ft-7-in.-diameter opening located approximately in the center of the car. Special transfer car inserts adapt the transfer car opening to the casks. When a shipping cask, charger, or other container arrives at the storage facility, the proper transfer car insert and in some cases an additional adapter plate is placed in the transfer car opening to support the container in the transfer car.

Six steel baffle plates are located on the deck of the transfer car. The baffles are the same width as the transfer car and extend approximately 2 ft above the deck of the car. Three each of the baffles are bolted to each end of the car and are enclosed in 1-in.-thick steel plates to form shielding boxes 4 ft 9 in. long, the same as the thickness of the shielding wall between the fuel handling cave and the cask receiving area. When the transfer car is fully positioned in either area, a shielding box completely closes the hole in the shielding wall. Each box provides a minimum of 12 in. of steel for radiation shielding. Both the shielding boxes and the sides of the transfer car itself are provided with 1-in.-high 16-gauge stainless steel wipers that assist in isolating the handling cave from the PCS for ventilation control. A discussion of the shielding function of the transfer car is given in Subsection 6.1.1 of this SAR.

A removable center baffle is also available. This is a 6-in.-thick steel plate that fits into a frame located directly over the center of the hole in the cask transfer car.

For decontamination purposes, the upper surface of the cask transfer car, including the inside[b] edges of the shielding boxes, is clad with 1/8-in.-thick type-304 stainless steel. The remainder of the car is painted with paint that allows for easy decontamination.

---

b. Those portions of the boxes that enter both the fuel handling cave and the cask receiving area.

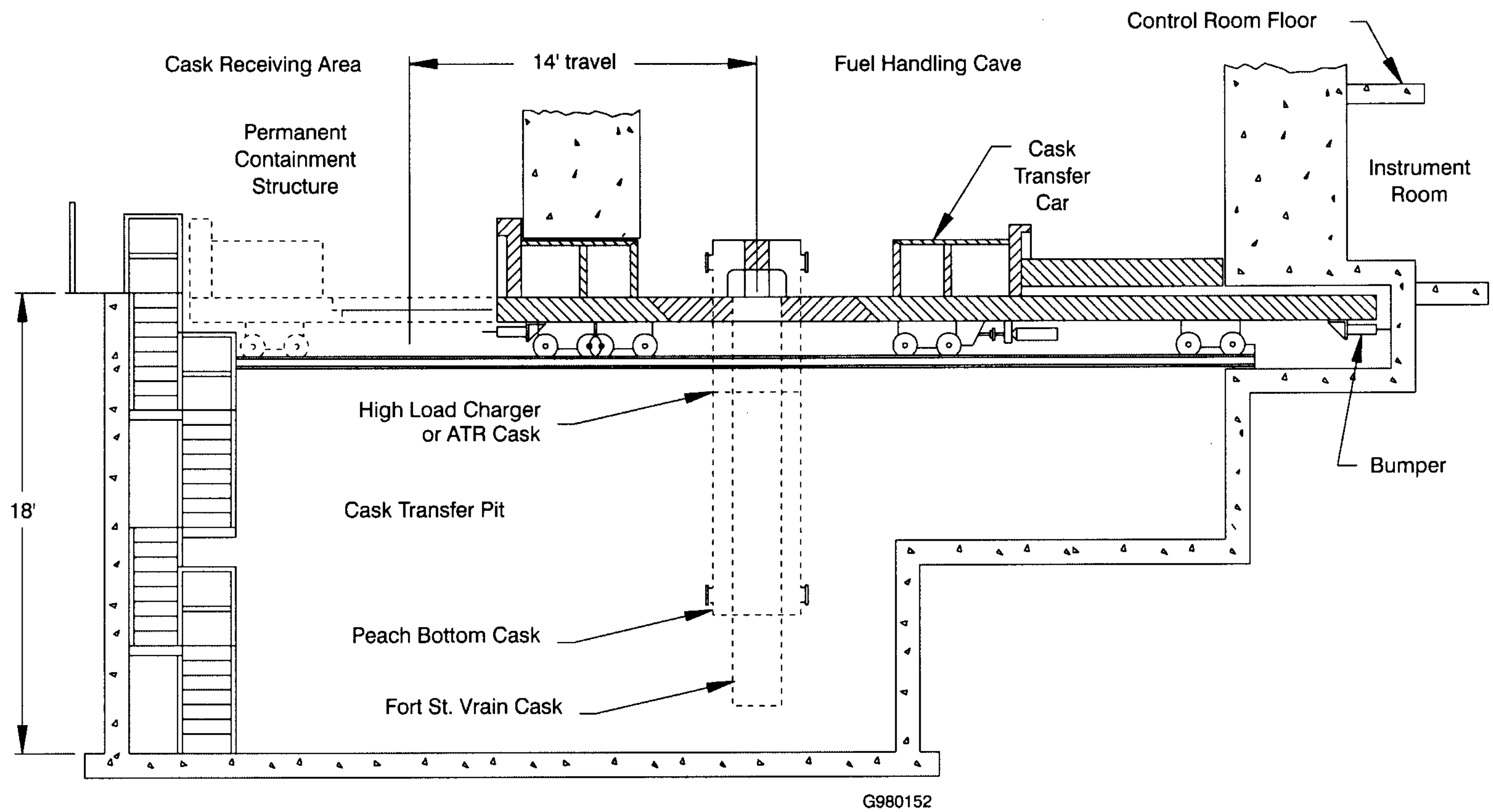

Figure 4-2. Cask transfer car.

The cask transfer car's electro-mechanical drive system is controlled from either the control room or the cask receiving area. The car travels at 10 ft/min in either direction, and its position is controllable to ± 1/4 in. Mechanical stops and bumpers capable of stopping the loaded car traveling at maximum speed are provided at both limits of travel. Operating procedures require that operators occupy both stations before the car is moved. Each control station includes two start buttons (one to start movement into the cave and the other to start movement out of the cave), a stop button, and blue position-indicating lights. In addition, the control room station includes a master lockout key switch that interrupts all power to the car control circuits. Interlocks prevent attempts to move the car in both directions at the same time, and limit switches prevent overtravel of the car. The transfer car is supplied with normal and standby power.

4.7 Shielding Door and Movable Crane Rail

An 11-in.-thick, movable steel shielding door that closes the opening between the top of a concrete shielding partition and the facility roof is provided in the storage facility. The door, composed of three approximately equal-sized sections, operates on tracks located on top of the shielding wall between the fuel storage area and the fuel handling cave. When the door is in the closed position, the stored fuel is isolated from the remainder of the facility, and the handling cave (if no fuel is present and the contamination level is low) and the crane maintenance area become reduced radiation zones permitting limited access to these areas for inspection, preventive maintenance, and equipment repair. When not needed for shielding, the door is retracted through the north shielding wall into a storage enclosure. The shield door cannot be completely closed if the shield plug is not in place.

The shielding door drive system consists of a 3-hp electric motor that drives two independent 3/8-in.-diameter closed wire-rope loops. One end of the wire-rope loop is attached near the front of the forward section of the door. The other end of the loop is attached to the rear of the same door section. A traction sheave drives the cable, which in turn pulls the shielding door open or closed. Through the use of overlapping end plates, the driven door section can engage and open and close the other two door sections.

If one of the two drive cables fails, the independent cable system will operate the doors. The electrical components and the mechanical portion of the drive are all outside the radiation area and may be serviced with the shielding doors open or closed. If the drive system should fail completely, the doors can be opened or closed by pulling the cables manually.

The door drive system is controlled from the facility control room and is capable of opening or closing the door in approximately 8 minutes. Limit switches backed up by bumper-snubber devices stop the door when the travel limits are reached. The bumper-snubbers are capable of stopping the door with the door traveling within its design speed.

The support rails on which the doors roll were replaced in 1990 and 1991.

Because the shielding door operates perpendicularly to the storage facility crane rails, the shielding door must cross the north crane rail as the door opens and closes. To permit door movement, a 7-ft-4-in. section of crane rail is motorized and pivots 90 degrees about one end. The rail is driven by an electric motor mounted in the facility control room. A drive shaft penetrating the control room ceiling engages gears mounted above the ceiling to move the rail through its 90-degree rotation.

The three-sectioned steel shielding door and the motorized section of the north crane rail operate together. If the door is open and the close button is pushed, the swing rail must open before the door can close. The control station for the door and rail is located in the facility control room and includes lockout switches on the rail and door motors and a key-operated master lockout switch on the control panel. An emergency lockout pushbutton is located on the north wall of the control room under the swing rail drive system. The system also includes limit switches to prevent rail and door overtravel and blue indicating lights to show the door position. A green light is illuminated any time the rail or door is in operation. The lockout key switch prevents inadvertent or unauthorized operation of the system. The door and rail limit switches are operated by physical contact with the respective unit. The shielding door is supplied with normal power. Loads on the 10-ton crane, CRN-GSF-101, are administratively controlled to 10 tons in the fuel handling cave and 3-1/2 tons over the mezzanine and shield wall, and in the fuel storage area to prevent failure of the swing rail during a seismic event.[8]

4.8 Shielding Windows

The facility has three shielding windows. Two are the original windows in the control room walls. The third window was installed in 1985 in the south wall between the fuel receiving area and the handling cave. This window provides visibility for operations using the remote manipulators, which are located next to the window.

4.8.1 Control Room Windows

Two shielding windows are provided in the storage facility control room walls. One window permits viewing handling cave operations, and the other, storage area operations. The windows are lead-glass shielded, oil-filled, and approximately 46 in. wide, 49 in. high, and 52 in. thick. They reduce radiation levels at the control room side, or cold side, of the windows to less than 0.25 mrem/h from a design radiation level of 50,000 rem/h, which was the expected radiation level of HTGR fuel elements. This source term has been shown to envelop a bucket containing eight ATR fuel elements placed next to the window, the highest source term for any of the canning station fuels.[9] The glass used is specified to be nonbrowning even after 2×10^8 rem of radiation.

The fuel storage area viewing window is provided with a 0.75-in.-thick lead cover plate installed on the fuel storage side of the window. The plate is hinged to allow it to be closed (rotated) from the facility control room to provide radiation shielding and protection when the window is not in use. The lead is encased in 1/4-in.-thick stainless steel to prevent slumping at storage area temperatures.

The shield cover plate that protects the fuel storage area viewing window is driven by a 1/20-hp electric motor in the control room through a driveshaft and worm gear arrangement. The drive shaft penetrates the shielding wall. Contamination is contained by a packing gland on the driveshaft. Additionally, a cover plate covers the penetration to provide a barrier to possible contamination spread. Also, the air pressure in the storage area is slightly negative with respect to the control room. The motor and limit switches are located on the cold side of the window. If the motor fails or the limit switches malfunction, the door can be driven by hand. The hand-drive requires the use of the same gear system on the hot side of the window. If these gears fail, the window can be opened and partially closed using the crane block, leaving a small opening to provide enough visibility to hook the crane block at the edge of the door.

Both windows are designed so that they can be removed from the control room side for repair or replacement. If fuel is stored in the storage area and it becomes necessary to remove the window to that area, it would be necessary to place temporary shielding over the opening for personnel protection.

The viewing requirements for the handling cave make it necessary to see the floor of the cave at a distance of 1 ft from the wall directly under the window. This requirement could not be met using a direct view through the window. Internal mirrors are installed in the handling cave window to provide visibility of this portion of the cave. This makes it possible to see all of the cave floor wells. A flat, stainless steel mirror also is attached to the fuel storage side of the storage area window to permit viewing areas of the fuel storage region not directly visible through the window.

4.8.2 Fuel Handling Cave and Fuel Receiving Area Window

To provide the capability to repackage fuels, two manipulators and a lead-glass, oil-filled viewing window were installed in 1985 in the wall between the receiving area and the handling cave. The concrete wall is 4 ft 9 in. thick. The window, including its frame, has a shielding capability to reduce the radiation level at the cold side to less than 0.125 mrem/h from a design radiation level of 50,000 R/h at the hot-side glass.[10,11,12] The containment glass assembly is on the handling cave side of the wall. A purging gas can be introduced between the window assembly and the containment glass assembly.

The window was designed to allow its removal from the cold side for repair or replacement without breaking the containment seal. The window can provide a 130-degree combined extreme field of view through the 4-ft-9-in.-thick concrete wall. The window is also designed to prevent light transmission from degrading more than 30% after an accumulated radiation exposure to 2×10^8 R.

4.9 Shielding-Wall Plug

As discussed in Subsection 4.5, the bridge-mounted manipulator is capable of complete coverage of the storage facility. However, because of the manipulator arm length, the arm cannot be retracted sufficiently to allow the manipulator to pass over the top of the shielding wall separating the fuel storage area from the fuel handling cave. Therefore, to permit manipulator passage, a removable plug has been installed in the top of the wall approximately 4 ft from the south end of the wall. The plug is constructed of three pieces of carbon steel (two fixed and one removable) that fit together to form a 12-in.-thick, 24-in.-wide, and 50-in.-high unit. When all three sections of the plug are installed in the wall, complete closure of the shield door is possible. When the removable plug section is removed, the manipulator can pass from the handling cave to the storage area. The total weight of the removal plug section is approximately 1 ton. The design of the removable plug section may preclude a drop into the storage area by limiting the lift height.

4.10 Television System

To aid in initial operator training and to increase visibility during fuel handling operations, TV cameras can be mounted on the trolley of the 10-ton crane in the storage area and on the bridge-mounted PaR manipulator. These cameras have zoom capabilities. The cameras provide a visual aid in the immediate area where the crane hook engages a storage canister lifting bail. Control-room-mounted monitors are included as part of each TV system. To prevent unnecessary damage to the camera mounted on the trolley of the 10-ton crane, administrative procedures require the crane, during periods of nonuse, to be positioned in the handling cave. Other cameras may be positioned in selected locations within the facility to aid in remote operations and fuel accountability.

4.11 Lighting

Standard fluorescent, mercury-arc, quartz-iodide, and incandescent lights are used to illuminate the fuel storage facility. The lights are arranged as described below.

4.11.1 Fuel Storage Area

Eight mercury-arc flood lights are installed in the fuel storage area in four rows, each containing two lights. Each light is installed in a trolley suspended from a three-phase feed rail. The feed rails are installed on the facility ceiling between the prestressed concrete roof beams. For repair or replacement, the lights and trolleys can be withdrawn from the facility through hinged shielding doors installed in the north wall of the storage area. These light access doors can be reached by use of a ladder or a "cherry picker." The shielding doors consist of a 5-in.-thick steel frame filled with lead shot. Buna-N rubber gaskets seal the doors to prevent air or water leakage.

4.11.2 Fuel Handling Cave

Ten mercury-arc lights illuminate the fuel handling cave. These lights are installed on three of the cave walls about 17 ft above the cave floor. A wire-mesh guard encloses each lamp to protect it from damage.

4.11.3 Crane Maintenance Area

Three mercury-arc lights are installed in the crane maintenance area.

4.11.4 Crane Trolley

One quartz-iodide light is installed on the crane trolley. This light provides additional visibility in the immediate area of crane operations and illumination for the crane-mounted TV camera. A transformer is mounted on the trolley to allow a 440-V power feed through the cable reels to reduce the current load in the conductors.

4.11.5 Control and Instrument Room, Standby Generator Room, and Shielding Door Enclosure

The control and instrument room, the standby generator room, and the entry hall between CPP-603 and the facility control room are all provided with standard fluorescent light fixtures. The shielding door enclosure contains an incandescent fixture.

4.11.6 Cask Transfer Pit

One incandescent light is provided in the cask transfer pit. This light is positioned so that it illuminates the stairway and a portion of the cask transfer pit in the cask receiving area.

4.11.7 Cask Receiving Area

Six mercury-arc lights illuminate the cask receiving area. Three additional mercury-arc lights are located outside the cask receiving area above the rollup doors. These illuminate the truck ramp and the railroad spur.

4.11.8 Standby Lighting

Four of the mercury-arc lights, one in the crane maintenance area, two in the fuel handling cave, and one in the cask receiving area, are connected to the standby power system. Upon a loss of normal power, these lights are automatically switched to the standby power system. Mercury-arc lamps, however, require a warmup time of approximately 10 minutes. Thus, when the power switches from either normal to standby or from standby to normal, all mercury-arc lamps are off for about 10 minutes. To provide adequate lighting during these 10-minute warmup periods, incandescent lights have been installed in the three areas with the mercury-arc lights. These incandescent lights are connected to the standby power system through a timer and operate for about 10 minutes (enough time for the mercury lamps to warm up and begin operating) each time that the power switches from one system to the other.

4.12 References

1. Idaho Chemical Processing Plant Drawing 154872, "CPP Phase II, Bldg 603 Irradiated Fuel Storage Facility (HTGR) Fuel Element Storage Can," October 25, 1974.

2. Idaho Chemical Processing Plant Drawing 448646, "CPP-603 IFSF Fuel Canning Station Canister and Lid Assembly," August 21, 1995.

3. Idaho Chemical Processing Plant Drawing 055116, "Irradiated Fuel Storage Rover Fuel Storage Canister Insert," October 29, 1974.

4. G. K. Miller, letter to F. T. Wilkins, "Evaluation of ATR Fuel Elements for Seismic and Handling Loads Associated with Storage in IFSF Storage Rack," GKM-12-97, October 27, 1997.

5. A. J. Palmer, Rerate CPP-603 IFSF Shuttle Bin, Engineering Design File INEL-96-284, September 20, 1996.

6. Sargent Industries Central Research Laboratories, Inc., Installation, Operation, and Maintenance Manual for the Model F Rugged-Duty Master-Slave Manipulator, Red Wing, Minnesota, October 23, 1981.

7. EG&G Idaho, Inc., "Purchase Specification for Master-Slave Manipulators," EA98937-2, August 3, 1983.

8. M. J. Shannon, letter to R. D. Denney, "Evaluation of IFSF Swing Rail," SHA-01-91, January 11, 1991.

9. D. R. Wenzel, letter to W. A. Kyes, "Adequacy of IFSF Shield Windows for ATR Fuel Handling," WEN-04-96, February 27, 1996.

10. A. D. Summers, letter to H. D. Welch, "CPP-603 Manipulator Shielding Analysis," ADS-2-84, February 15, 1984.

11. A. D. Summers, letter to H. D. Welch, "CPP-603 Window Shielding Analysis," ADS-4-84, March 9, 1984.

12. A. D. Summers, letter to H. D. Welch, "CPP-603 Window Frame Shielding Analysis," ADS-7-84, May 2, 1984.

5. ANCILLARY SERVICES

CONTENTS

5. ANCILLARY SERVICES

5.1 Utilities

The existing INTEC utilities system[1] provides general services to the IFSF via interconnections with CPP-603. Common utilities are supplied to CPP-603 from the main INTEC supply headers. Services for the IFSF include electricity, steam, air, and various water supplies.

5.1.1 Electrical

The IFSF is supplied with 110-V and 220-V receptacles and welder and telephone outlets in sufficient quantity to conform to the National Electrical Code and general site practice. Normal electrical power (120-V and 480-V) is obtained from CPP-603 and is fed to the transfer switch through load center 4. Electrical power for the Fuel Canning Station is hard-wired into the handling cave from motor control center (MCC) MCC-SF-327 through MCC-329.

A propane-fueled generator has been used at the IFSF to provide standby electrical power. This generator is being replaced by the INTEC standby electrical power bus. At the completion of SO testing of the new system, scheduled for late fiscal year 1996, the propane system will no longer be used.

5.1.2 Steam

Steam for the storage facility is obtained from an existing 4-in. line that supplies 130-psig saturated steam to CPP-603. Within the IFSF, the steam is used in the crane maintenance area decontamination pad, and in the cask receiving area and the control room for space heating. The steam line is connected and disconnected outside the cell. The line must remain disconnected at all times unless operators are present to monitor for condensate formation in the fuel handling cave.

5.1.3 Air

Plant and instrument air are obtained from the 90-psig, 40-ft^3/min, air compressor that supplies air to CPP-603. Air is available in several areas of the IFSF, including the cask receiving area, the fuel handling cave, the crane maintenance area, and the control room. The air is used primarily for control instrumentation, maintenance, and decontamination work. Breathing air can be obtained from self-contained breathing apparatuses for emergency use and from a portable breathing air compressor for longer-term use.

5.1.4 Water

Water for CPP-603 is obtained from the 10-in.-diameter fire-water line that supplies raw water at a static pressure of 135 psig. This water is not available in the IFSF portion of CPP-603, except (1) in the cask receiving area for removing road dust from casks and trucks and for decontaminating empty casks and (2) for a safety shower in the access hallway between CPP-603 and the facility control room. Drinking water and sanitary facilities are located in the FSB change room (CPP-626), which is adjacent to CPP-603.

PSD Section 3.1 provides a detailed description of the fire-water system.[2]

5.2 Ventilation System

The functions of the ventilation system are (1) to remove the decay heat generated by the stored fuel, (2) to provide ventilation for the facility, and (3) to maintain an airflow pattern within the facility that is always from a less contaminated area to a more contaminated area. Because of the decay heat associated with the stored fuel, a design value of approximately 1.2×10^6 Btu/h for a full[c] facility, the stored fuel is cooled by a forced-flow, single-pass air system. This system is capable of supplying a cooling airflow of up to 14,000 ft^3/min to the storage area.

Before entering the facility, the inlet air passes through roughing filters to remove dust and foreign materials. Before being discharged to the atmosphere through the facility stack, the exit air passes through prefilters and HEPA filters to remove any particulate matter and is then monitored to detect activity. A detailed discussion of the ventilation system appears in Subsection 6.2.

5.3 Communications System

Storage facility communication systems include those for voice, fire, evacuation, facility entrance, and telephones.

An intercom system is provided in the storage facility for direct voice communication among the different areas. The control unit is located in the facility control room; remote units are located in the crane maintenance and cask receiving areas.

The CPP-603 fire alarm system includes the fuel storage facility. There are seven fire alarm pull boxes in CPP-603. One is located between the crane maintenance area and the standby generator room for easy access from the IFSF. When activated, a fire alarm pull box transmits a signal within the INTEC area and at the Central Fire Station. A voice paging system alerts personnel of a fire and informs them of the area in which the fire is located. Fire protection is discussed further in Subsection 8.4.

A switch in the IFSF control room will initiate either a local evacuation alarm or a local take-cover alarm. The IFSF CAS is connected to the sitewide evacuation system. In addition to CAS logic which automatically initiates the sitewide evacuation alarm, the IFSF CAS Data Acquisition System 8 (DAS 8) also has a manual control which can initiate the criticality alarm, and this automatically initiates the plantwide evacuation as well. (See Section 6.1.2.3.) In addition, the INTEC evacuation siren can be activated by the areawide switches in the plant shift supervisor's office (CPP-602), the Emergency Control Center (ECC) (CPP-652), and the New Waste Calcining Facility (CPP-659). Personnel in the cave must be able to hear any evacuation alarm without having to depend on personnel outside the cave to notify them.[3]

There are two switches that initiate security alarms: one for the door to the crane maintenance area, and the second for the shuttle bin. Because both areas could be very high radiation areas, alarms are provided to indicate personnel entrance into these areas. Additional security controls are discussed in Subsection 5.4.

A telephone is located in the IFSF control room.

---

c. Worst case: 120-day cooled Peach Bottom and Fort St. Vrain fuel.

5.4 Security System

The safeguard security system at the IFSF includes the physical and administrative controls to prevent the unauthorized diversion of fissionable materials. The security system includes controlled access to the shuttle bin and the 10-ton crane and an administrative control requiring the presence of two people whenever the shuttle bin or the 10-ton crane is operated. Additional security features for the IFSF are explained in the Site Safeguards and Security Plan and the IFSF Security Plan.

5.5 References

1. PSD, Section 4.1, "Utilities."

2. PSD 3.1, "Safety Analysis of the ICPP Water, Steam, and Fire Suppression Systems."

3. ANSI/ANS 8.3-1986, "American National Standard Criticality Accident Alarm System," American National Standard Institute/American Nuclear Society.

6. ENVIRONMENTAL AND PERSONNEL PROTECTION SYSTEMS

CONTENTS

FIGURES

TABLES

6. ENVIRONMENTAL AND PERSONNEL PROTECTION SYSTEMS

The environmental and personnel protection systems at the IFSF were specifically designed for the handling and storage of highly irradiated HTGR fuels. Therefore, the IFSF was constructed and equipped (1) to minimize radiation exposure to operating personnel and surrounding areas; (2) to limit decay heat temperatures to a value that would not damage the fuel or the facility's structural integrity; and (3) to prevent gaseous, liquid, or solid waste from entering the environment in concentrations exceeding state and federal environmental protection limits.

These functions are also provided for handling and storage of the other types of fuels approved for storage in the IFSF.

6.1 Radiation Control

6.1.1 Shielding

The primary function of shielding in the IFSF is to reduce to ALARA levels the radiation hazard to personnel from the fuel in the facility during handling and storage. Subsection 6.1.1.1 discusses the designed radiation shielding capacity of the facility as related to the static condition of fuel storage. During certain operations in the fuel handling cave, radiation has been observed to stream through penetrations in the shield walls. These phenomena and other potential "leaks" in the shielding are discussed in subsection 6.1.1.2.

6.1.1.1 Shielding Capacity for Fuel Storage. The original design criteria[1] intended for the facility structure to provide sufficient shielding so that areas immediately surrounding the facility were limited to 2.5 mR/h, the control room to 0.25 mR/h. The IFSF was originally designed to store irradiated fuel from high-temperature gas-cooled reactors. Early calculations of the adequacy of the facility shielding,[2] therefore, used that fuel type as the source term. The shielding analysis in Reference 2 assumed that each storage area rack position held a canister containing four Fort St. Vrain reactor elements each. The fuel was modeled as having a burnup of 10,000 megawatt-days per metric ton of uranium and being 180 days out of the reactor. This very conservative source term yielded radiation fields at contact with the outside walls of the facility (including the shield wall between the fuel handling cave and the control room) that ranged from 0.016 to just under 3 mR/h. Calculated fields on the roof were between 60 and 260 mR/h. Actual stored fuels have not been as highly radioactive as assumed in these early calculations. However, when new fuel types are to be added to the facility, they are compared to this source term to determine that they fit within the design basis. This comparison is performed and documented by specialists in radiological safety (e.g., see References 3 and 4).

In addition to the shielding analysis, actual radiation measurements on the outside of the IFSF shield walls are occasionally performed. This is done after the receipt of new fuel types that could reasonably be expected to change the radiation fields external to the shield walls (e.g., See References 5 and 6. Both analytical results and measured values show that dose rates external to the facility, except on the roof, are lower than 5 mrem/h. If this level were exceeded, these areas would be posted as radiation areas, or additional shielding would be provided.

Personnel working on the IFSF roof could theoretically be exposed to radiation fields above 5 mrem/h (the most recent actual measurements show dose rates to be well below this level). For this reason, access via the ladder that leads to the roof is administratively controlled. An approximately 6 ft 9 in. square roof hatch over the crane maintenance area with a 3 ft 4 in. thick concrete cover provides access to the crane bridges. Lead-shielded doors in the north shield wall of the storage area immediately below the roof provide access to the lighting fixtures in the storage area. Any work that involves opening the roof hatch or the lighting access doors is performed in compliance with the INEEL Radiological Control Manual.[7]

Near the northwest corner of the IFSF, the ventilation ducting penetrates the north wall to supply cooling air to the storage rack. The penetration, which is partially below grade level, is shielded by a sloped earth mound. Radiation measurements at this earth shielding indicate that it is at least equivalent to the concrete wall. Disturbance of this earth mound, if it becomes necessary, is controlled by facility management.

6.1.1.2 Shield Penetrations and Fuel Handling.

Cask Transfer Car Pit And Opening in the South Shield Wall of the Fuel Handling Cave

The transfer car is described in Subsection 4.6 of this SAR. Under most conditions, the transfer car design provides shielding for personnel in the cask receiving area from radiation originating in the fuel handling cave. However, radiation streaming has been observed in the cask receiving area under certain conditions. One of these streaming conditions occurs when the transfer car is being moved while there is radioactive material in the cave, above the level of the steel-plate floor of the cave. It exists for only a few seconds while the shield box on one end of the transfer car is leaving the opening in the shield wall and before the box on the other end has engaged that opening. Typically, the stream emerges from the south wall opening in an easterly to southeasterly direction into the cask receiving area. Shielding material (lead blankets) has been installed to keep radiation exposures of the transfer car operator (outside the south wall, just to the east of the PCS) ALARA.

The other streaming condition has been observed at the south wall of the PCS and in the areas south of the PCS. This radiation stream is also of short duration, and has been observed as radioactive materials were lifted from a cask in the transfer car inside the fuel handling cave. It appears that for certain combinations of cask and inserts or adapters a gap exists between the rim of the hole in the transfer car deck. This gap allows radiation to stream into the transfer car pit, and from there reflect to the locations at the south of the PCS. This radiation stream exists only for a short time period while the radioactive material is lifted from the cask and before it is moved west to the floor wells or shuttle bin. The magnitude of this stream depends, aside from the source strength, on the size of the cask and the particular transfer car insert and adapter plates used. Potential radiation exposures to personnel in the cask receiving area are controlled in compliance with the INEEL Radiological Controls Manual, i.e., posting the affected area as a radiation area.

Personnel Access Door to the Crane Maintenance Area (CMA)

Personnel access to the crane maintenance area, and the fuel handling cave, is through a doorway with double doors in the north side of the CMA. The interior wall that divides the crane maintenance area from the fuel handling cave does not extend to the ceiling to allow the crane to travel into the crane maintenance area. For certain conditions, radiation from radioactive material in the fuel handling cave is reflected off the facility ceiling and impinges on the external personnel access door. This can create an area of higher-than-background radiation on the bottom left exterior of this door exceeding 5 mrem/h (the threshold for establishing a radiation area). Shielding has been added to the door. This will reduce radiation fields for most fuel handling operations to below 5 mrem/h on the outside of the door. If that level is exceeded, personnel exposure in that area will be controlled in compliance with the INEEL Radiological Control Manual.

Shield Door and Shuttle-Bin Shielding

Personnel enter the fuel handling cave on occasion to perform manual tasks that cannot readily be performed by remote manipulation. To reduce radiation levels in the fuel handling cave during such occasions, the shielded door that rides on rails on the top of the well between the cave and storage area can be closed. Also, the shuttle bin is moved fully into the storage area. The shuttle bin opening in the shield wall is then closed with the shuttle bin shield plate. This shield plate does not necessarily fit flush against the shield wall opening. In one specific case, radiation streaming around the edges of the shield plate was controlled by rearranging storage locations of certain fuel storage canisters, but this may not always be possible. To keep personnel exposures ALARA, all work involving personnel entry into the fuel handling cave is conducted with radiological monitoring under the provisions of the Radiological Control Manual.

6.1.2 Monitoring Equipment

The IFSF is provided with radiation detecting and indicating instruments that alarm upon sensing a high radiation level. The IFSF also has a CAS to warn facility and INTEC personnel of the occurrence of a criticality. The IFSF radiation monitoring equipment is described in the following paragraphs.

6.1.2.1 Continuous Air Monitors. CAMs detect airborne radioactive contamination (beta and gamma) by continuously sampling the air in a given area. These instruments also indirectly give warning of high radiation fields. Audible and visual alarms alert personnel to the presence of airborne contamination or high radiation fields.

CAMs at the IFSF monitor the facility's stack, the crane maintenance area, the fuel handling cave, and the PCS. The stack and handling cave CAMs are located in the radiological control technician (RCT) office on the first floor of the facility (below the control room). Both units provide continuous surveillance for these areas. The cask receiving area CAM, which monitors the PCS, is placed in operation only during fuel transfers.

Radioactive gaseous discharge from the storage facility stack is monitored and recorded by the stack effluent CAM. The system is not isokinetic. The system is not classified as a stack monitor for release data reporting purposes. This CAM has a range of 50 to 50,000 counts per minute and a high-range alarm point of 10,000 counts per minute. The system continuously draws a 0.5 to 1.0 ft^3/min air sample from the stack effluent stream, passes the sample through a HEPA filter, then returns the sample to the stack. The presence of radioactivity in the sample stream is determined by continuously monitoring the filter with a Geiger-Muller (GM) detector connected to a recorder and an alarm. This system would be capable of qualitatively detecting the presence of radioactive noble gases and their particulate daughters in the event of a criticality, but cannot make quantitative measurements.

The stack effluent sampling and monitoring CAM also provides taps for obtaining "grab" samples of the stack effluent. These samples can then be analyzed for potential radioactive gases such as H-3 and Kr-85.

Periodically, the CAM particulate filter is removed and counted for gross alpha. If an abnormal release is detected, the filter is removed, dissolved, and analyzed to identify the specific radionuclides collected on the filter.

After fuel had been handled and stored in the IFSF for 8 years, a study was performed to determine whether the facility effluent environmental control systems had been performing adequately. The study consisted of collecting and analyzing stack effluent for radioactive particulate emissions for 4 weeks. CAM filters were used to collect samples for 1 week, and each filter was then analyzed for gamma-emitting radioactive particulate (cesium-137, iodine-131, ruthenium-106, and antimony-125). The four filters obtained were dissolved and composited into one 1-month sample for analysis for plutonium-238, -239, and -240; cesium-137; and strontium-90. The results of the weekly and monthly analyses are presented in Table 6-1. The monthly composite values showed concentrations of plutonium-239 and -240 and strontium-90 that were at least four orders of magnitude lower than the allowable release concentrations.

Based on the above analysis, the levels of radioactivity measured at the point of release from the IFSF stack are at least 700 times less than the derived concentration guide (DCG) in DOE Order 5400.5.[8] Their contribution to the total INTEC atmospheric releases is negligible.

The radionuclide concentrations listed in Table 6-1 were used collectively as a source term to determine the off-site dose.[9] These results indicated that in 1 year the effective dose equivalent (EDE) is less than 1 mrem and the dose equivalent is less than 3 mrem to a member of the public. In accordance with DOE Order 5400.5, only periodic confirmatory sampling and analysis are required.[10]

The ventilation system particulate filters can be surveyed for radiation, and the detection of a sudden increase in the radiation level would indicate a release. The filters could be dissolved and analyzed to identify specific nuclides and to estimate release quantities should this ever be needed.

6.1.2.2 Radiation Area Monitors. RAMs are provided in the fuel storage facility to detect direct radiation levels and alert operating personnel to potential radiation hazards. Detectors are located in selected areas of the facility. The detectors provide a signal to rate meters in the control room so that continuous indications of the facility radiation levels are available. Each RAM actuates a local alarm and an alarm light in the control room upon detecting a high radiation level in the facility. The alarms can be reset in the control room.

The location and detection ranges of each RAM in the IFSF are listed in Table 6-2. See Figure 3-1 for location corresponding to listing in the Table 6-2.

6.1.2.3 Criticality Alarm System. The IFSF is equipped with a CAS to alert personnel to an occurrence of a criticality. The CAS is capable of activating facility warblers and the INTEC plant evacuation alarm in the event of a criticality. The IFSF CAS includes two detector clusters, R-GSF-801 and R-GSF-802, with three detectors per cluster; Data Acquisition System 8 (DAS-8); warblers to alert personnel to a criticality; an uninterruptible power supply (UPS); and associated cables and conduit. The CAS uses neutron detectors because the presence of a significant quantity of neutrons is indicative of a criticality. The system operates on a 2-out-of-3 alarm logic. This logic requires that two detectors in a cluster indicate a criticality before the evacuation alarm and warblers activate. The system is also activated if one or more detectors fail and another in the same cluster is in the high alarm state.

One detector cluster, R-GSF-801 (also called cluster A), is located in a spare manipulator port between the control room and the handling cave. This detector cluster provides coverage for activities in the handling cave. The second detector cluster, R-GSF-802 (also called cluster B), is located in the cask receiving area at the southeast corner of the shielded area. This detector cluster provides coverage for the cask receiving area CAS coverage zone, including the PCS.[11,12,13,14,15,16] The CAS coverage zone includes that portion of the cask receiving area which is contained within the boundary indicated in Figure 6-1. It extends from the floor level (including the level, below-grade portion of the west truck ramp) up to the

Table 6-1. Concentrations of radionuclides collected from the IFSF stack filter during August 1983.[a]

Collection Date	Radionuclide	Concentration (μCi/ml)	Derived Concentration Guides[8] (μCi/ml)
August 4, 1983	Cs-137	< 4.9E-15	4E-10
	I-131	< 6.9E-15	4E-10
	Ru-106	< 8.4E-14	2E-10
	Sb-125	< 9.7E-15	3E-09
August 11, 1983	Cs-137	< 5.1E-15	
	I-131	< 2.8E-15	
	Ru-106	< 2.0E-14	
	Sb-125	< 1.4E-14	
August 18, 1983	Cs-137	< 2.1E-14	
	I-131	< 1.4E-14	
	Ru-106	< 5.6E-15	
	Sb-125	< 4.7E-14	
August 25, 1983	Cs-137	1.3E-13	
	I-131	< 9.6E-15	
	Ru-106	< 5.6E-14	
	Sb-125	<6.1E-14	
Monthly composite	Sr-90	2.3E-15	9E-12
Monthly composite	Pu-238	< 2.0E-17	3E-14
Monthly composite	Pu-238 and -240	2.6E-17	2E-14
Monthly composite	Cs-137	3.6E-14	4E-10

a. The HEPA filter in the stack gas sampling system was changed weekly during the month of August of 1983. Each filter was dissolved and the resulting diluent analyzed for gamma-emitting radioactive particulate. The diluents were then composited and analyzed for Sr-90, Pu-238, Pu-239 and -240, and Cs-137.

Table 6-2. RAM detector locations.[a]

Detector Identification	Location
1. RAM/4 GSF-42	Control room south wall, by cave window
2. RAM/4 GSF-44	Under transfer car in transfer pit
3. RAM/4 GSF-46	Cask receiving area by transfer car controls

a. Alarm setpoints are set in conformance with the INEEL Radiological Control Manual.[7]

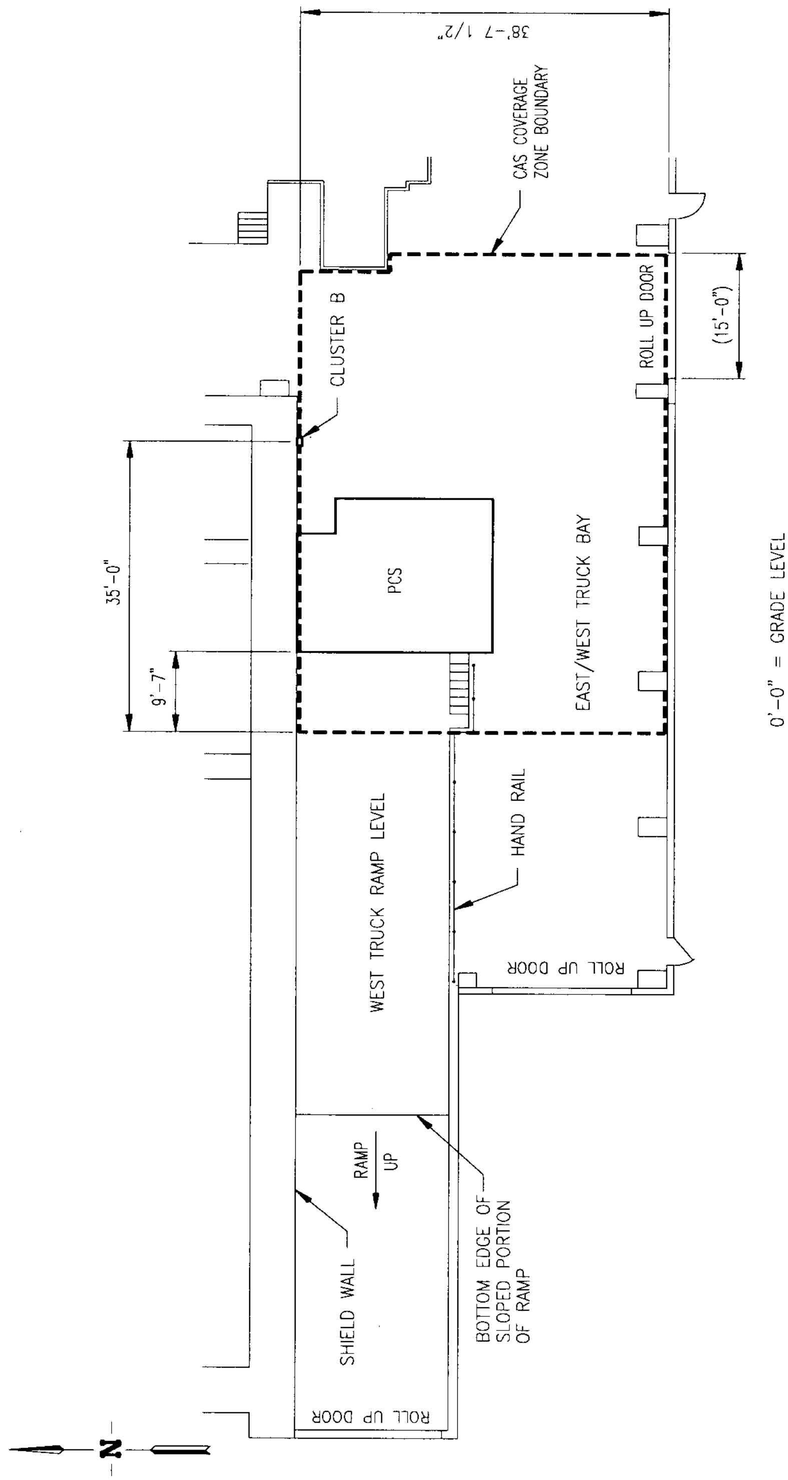

Figure 6-1. CAS coverage zone.

height of the crane rail. Fuel handling in the zone is subject to the following specific requirement related to CAS detection:

> When a direct, straight-line neutron path (usually a direct line of sight) is maintained between Detector Cluster B of DAS-8 and the fissile material being handled, fuel handling is allowed in the defined CAS coverage zone.

NOTE: The CAS coverage zone has no restrictions on the number of persons that may be handling fuel in the area between Cluster B and the fuel being handled. However, fuel handling is not allowed whenever shielding objects (e.g., casks, drums, crane pendants) block the direct neutron path between it and detector Cluster B.

Reference 11 shows that the sheet metal walls of the PCS may be considered transparent to the neutron path. The CAS coverage zone extends vertically from the building floor (including the bottom, below-grade portion of the truck ramp) to the height of the crane rail.

Reference 11 evaluated various cases that modeled obstructions designed to simulate persons, casks, drums, and other shielding in various locations in the CAS coverage zone where they would block a direct neutron path between a postulated criticality event and Detector Cluster B. The below-grade concrete wall at the east end of the truck ramp, the metal PCS walls, and the PCS doors were either modeled directly or enveloped 12 in all applicable cases in the referenced report. The analysis showed that neutron back scatter is sufficient for Cluster B to detect a minimum criticality at the bottom of the truck ramp west of the PCS, even though the direct neutron path may be impeded by the concrete wall of the transfer car pit. The thickness of the stainless steel walls and doors of the PCS does not block the neutron path sufficiently to prevent cluster B from detecting a minimum criticality beyond the PCS from Cluster B. Shielding in the form of a solid annulus of two-deep human bodies does not prevent detection of a criticality in the defined CAS coverage zone. Although two persons could shield a direct neutron path from a minimum criticality event to the detector cluster, calculations show that there would be sufficient neutron backscatter from the concrete floor for detection at Cluster B.[13]

CAS coverage of fuel handling within this zone is required for any fuel handling operation in which fuel/fissile material is not in closed shipping/transfer containers (e.g., not in closed casks, chargers, or 6M drums). Restricting out-of-container fuel handling to the CAS coverage zone assures adequate coverage by the criticality alarm system.

The CAM monitoring the facility stack (CAM-GSF-01), as described in Subsection 6.1.2.1, is capable of detecting a fission product release should a criticality occur in the storage area. Both this CAM and airflow, as provided by facility blowers, are needed to assure detection of a fission product release. Therefore, CAM GSF-01 should be operating, and airflow to the stack provided during fuel movement in the fuel storage area. The CAS detector, providing coverage in the fuel handling cave, R-GSF-801, may also be able to detect a criticality in the storage area. Because the storage area is a well-shielded area and is never occupied by persons, this criticality detection system is in conformance with DOE Order 5480.24.[17] An evacuation signal is not required. A well-shielded area is an area in which the resultant dose to the worker is less than 12 rad in free air from a fission criticality event. In the IFSF storage area, the credible postulated criticality events occur in one of the canisters and this canister is not directly up against the wall. The edge of the critical sphere in the canister is 9.25 inches from the west side of the shield wall between the fuel handling cave and the fuel storage area. The sphere center is 10.74 inches below the top of IFSF control room floor. The resultant dose in the radiological control room and the control room from a criticality event with the added distance from the wall included is 1.56 rad in free air.[18]

The fuel handling cave is a shielded area. However, occasional hands-on fuel handling is conducted in the cave (e.g. Rover fuel handling). Also, a postulated criticality event may be directly against the outside (or control room) walls. The total dose estimate for a 1.0E+18 fissions criticality event up against a 4 feet 9 inches thick concrete wall results in a total dose of approximately 15 rad in free air. Because of this postulated dose and the possibility of a criticality in this hands-on operation, CAS coverage is required in the handling cave during fuel handling as well as in the cask receiving area during hands-on fuel handling.

The CAS detector, R-GSF-801, in the manipulator port on the north wall of the IFSF fuel handling cave has the potential to inadvertently alarm if sufficient gamma radiation from the spent nuclear fuel (SNF) is present. This alarm will activate the facility warblers and the INTEC plant evacuation alarm. The ATR, ARMF/CFRMF, HFBR, MURR, ORR, TRIGA-Al, BMI-Spec, and WAPD fuels were analyzed to determine if any of these fuels has a sufficient gamma radiation to cause a high radiation level of the CAS detectors.[19,20] Of these fuels, the ATR fuel has the strongest gamma source term and the greatest potential to activate the CAS alarm, R-GSF-801. An exclusion zone will be used to limit gamma dose rates to the CAS detectors to < 4.2 R/hr. This limit is used to provide a margin of safety to ensure the CAS limit of 10 R/hr is not reached. The CAS detector has lead shielding around its lower half. A bucket with up to eight ATR elements can be moved freely about the IFSF cave, provided the eleven foot bucket lifting tool for aluminum plate fuel (TD-GSF-963-X) is used for lifting the fuel. This bucket lifting tool physically limits the fuel elements from rising above the CAS detector axial centerline elevation. However, in the cave the crane (either CRN-GSF-101 or CRN-GSF-401) is able to lift a fuel storage canister above the CAS detector axial center line and expose the unshielded portion of the detector heads to gamma radiation. This could result in a CAS alarm. Thus, in the fuel handling cave, a trapezoidal exclusion zone will be established for handling the ATR, MURR, ORR, and HFBR canisters, which will be loaded with fuel. The exclusion zone has the following dimensions: (1) along the cave north wall eight feet in each direction from the center of the CAS detector, (2) extends eight feet south from the north wall, (3) the south side extends six feet in each direction from the center of the CAS detector, and (4) extends from the floor to the ceiling. This exclusion zone represents the minimum distance ATR, MURR, ORR, and HFBR fuel must be kept away from the CAS. For the ARMF/CFRMF, WAPD, TRIGA-Al, BMI-Spec fuel and the CFRMF Core Filter there are no exclusion zones.[18,19,20]

A measured detector response to gamma radiation for any canister of ATR, HFBR, MURR, and ORR fuel can be obtained under test conditions. This test can only be performed with the following restrictions, which ensure proper notifications and preparations are made prior to the test.

1. An outage of the IFSF and Criticality Alarm System (CAS) must be in place.

2. The IFSF CAS must be fully operational but not connected to the local warbler and plantwide evacuation alarms. The CAS must be in calibration to be considered fully operational.

3. The only fuel movement allowed under the outage will be the movement of one canister of fuel in the IFSF cave out of approved storage, up to the CAS detectors, and back to approved storage. When the canister of fuel is directly up to the CAS detectors, it may also be moved around the CAS detectors to get additional radiation readings.

No criticality is postulated for this test for the ATR, MURR, ORR, and HFBR fuel type because the canister has been processed through the canning station (i.e., the fuel is dry inside) and the cave area is dry. The canister will remain subcritical in the event of a drop accident.[21,22]

The CAS uninterruptible power supply (UPS) can supply power to operate the CAS for at least 2 hours in the event of a commercial power failure.

6.1.2.4 Nuclear Accident Dosimeters. Nuclear accident dosimeters (NADs) are provided in the IFSF. Placement of the NADs is based on approved implementing procedures to ensure adequate coverage. In the unlikely event of a criticality, the NADs would be examined to determine the magnitude of the criticality and the resulting doses personnel in the operating areas received.

6.1.2.5 Portal Monitors. A portal monitor is located in the hallway leading from CPP-603 to CPP-626, which is adjacent to the north side of CPP-603 and contains the lunch room, the shower, and the locker room area. The monitor is positioned so that anyone exiting CPP-603 must pass through the detectors. The monitor differentiates and subtracts background radiation and is equipped with audible and visual alarms.

6.1.2.6 Self-Monitors. Self-monitors are located throughout the facility at the boundaries of locations where there is a possibility of personnel contamination.

6.1.3 Contamination Control

Areas within the IFSF are segregated into two types: (1) An area that is free of contamination is classified as a "clean" area. (2) An area that is not free of contamination is classified as a "contamination area." Contamination areas are further subdivided into "contamination" and "high contamination" areas, based on the level of contamination. The fuel handling cave, the fuel storage area, the PCS, the transfer car pit, and the crane maintenance area are classified as "contamination areas."

An area classification may be changed if warranted by existing conditions. Some clean areas may become contaminated during situations in which the inadvertent spread of contamination occurs, such as that which could result from a damaged cask in the fuel unloading area.

Details of the area system, including protective clothing requirements for each controlled area, are described in the INEL Radiological Control Manual.

RCT coverage within the INTEC is provided on a 24-hour-a-day basis. Coverage for the IFSF is provided on an "as necessary" basis, that is, RCTs are available when operating conditions require their presence, such as when a cask is transferred to or from the IFSF.

6.2 Decay Heat Removal And Contamination Control

Decay heat removal and contamination control are accomplished by the systems and equipment described in the following subsections.

6.2.1 Ventilation System

The primary functions of the ventilation system, schematically shown in Figure 6-2, are cooling the stored fuel and preventing the spread of radioactive contamination. As designed, the ventilation system is capable of maintaining the facility (except the control room) at a slight negative pressure and the storage area temperature at less than 200°F (366 K). The system is designed to direct airflow from lower to potentially higher contaminant concentration areas. Facility exhaust blowers are designed to have higher capacities than corresponding supply blowers to ensure inleakage. Normal airflow through the storage area is approximately 14,000 ft^3/min, but the ventilation system may also be operated at approximately

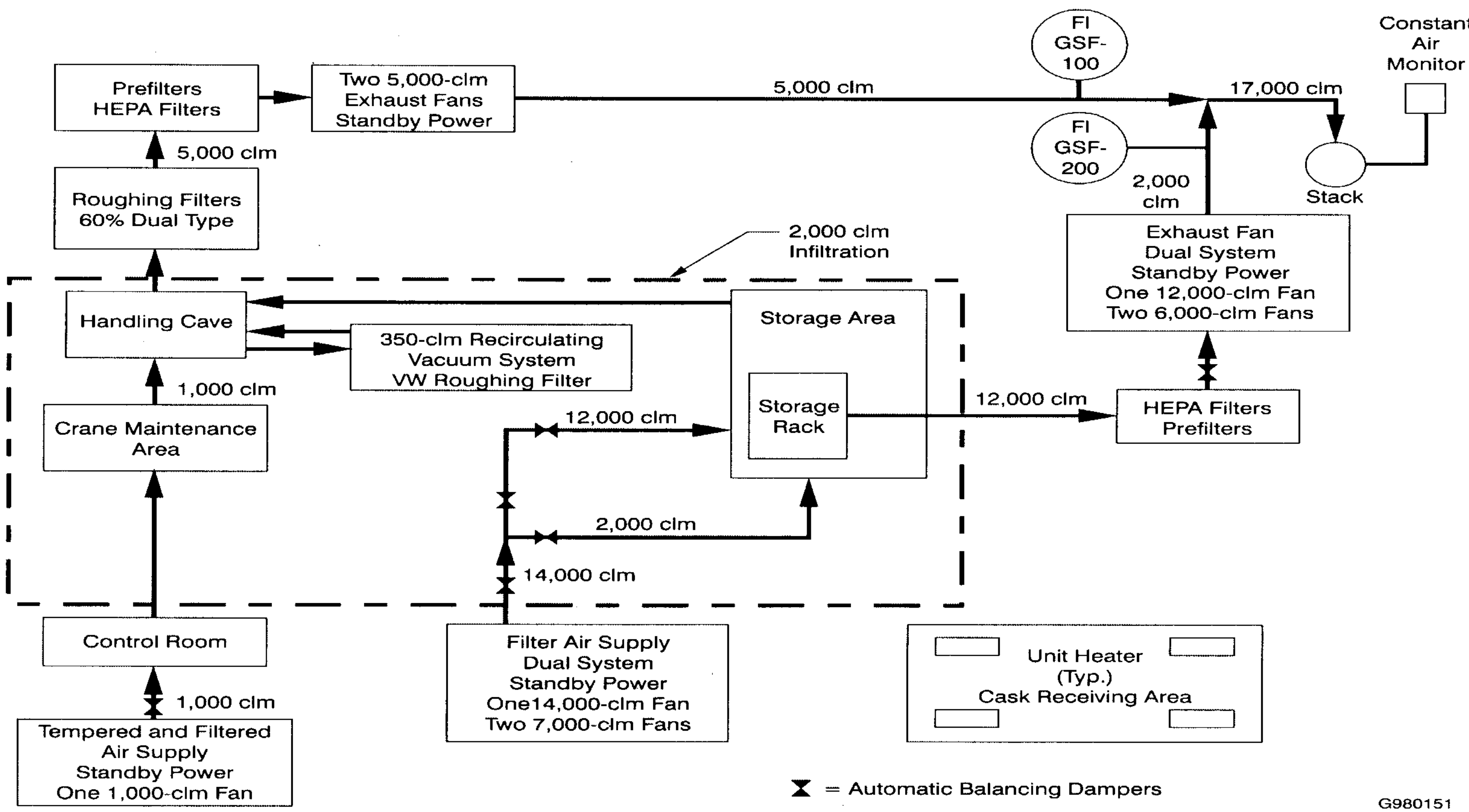

Figure 6-2. Schematic of heating and ventilation system.

7000 ft^3/min. The ventilation system was inspected in 1990 and necessary repairs and upgrades were completed in 1991, in accordance with UBC Zone 2B criteria, to ensure continued adequacy of the system in the event of a seismic event.

The facility ventilation system was designed with subsystems to allow operational flexibility while meeting the functional objectives given above. The PCS has its own exhaust blower equipped with HEPA filtration, which exhausts into the handling cave. When the transfer car is midway between the handling cave and the PCS, air can pass between the two areas. Therefore the PCS exhaust blower has an interlock that prevents the blower from operating unless the transfer car is in the PCS. This prevents the PCS from drawing potentially contaminated air from the handling cave.

6.2.1.1 Fuel Storage Area and Fuel Handling Cave. Filtered ambient (outdoor) air is directed through the fuel storage area and the fuel handling cave by a combination of supply and exhaust blowers. The cooling air enters the storage area in two streams: one contains about 85% of the air and flows through the storage rack, a second contains about 15% of the air and flows above the storage rack. There is also some inleakage of air into the facility.

The part of the air that flows through the storage rack enters the rack through a distribution plenum located at the west end of the rack (Figure 6-3). The plenum contains 18 openings, each 20 in. wide and 12 in. high, which distribute the air uniformly across the rack to ensure adequate cooling for each storage canister. After passing through the rack, the air exhausts through eight openings in the bottom of the east end of the rack and is then collected in an exit plenum. The inlet and exhaust opening doors were adjusted for uniform airflow and then welded in place.

The directed airflow ensures that the primary flow pattern is among the canisters. Because of the momentum of the air and the directed pressure differential, the majority of the air continues to flow below the rack surface and around the canisters when some canisters are removed from their storage rack positions. Seven storage rack positions located at the east end of the rack (row 38) are not in the direct flow path of the cooling air. The turbulence of the cooling air near the outlet openings provides adequate cooling to these few positions.

The air then passes through prefilters, HEPA filters, and exhaust blowers before being discharged to the atmosphere through a stack, the top of which is 65 ft abovegrade.

The air that enters above the storage rack cools the area above the top of the rack. This air enters the IFSF through two ducts located in the corners of the west end of the facility near the ceiling. After passing through the storage area, this air stream passes over the top of the shielding wall and enters the fuel handling cave. It combines with the 1000-ft^3/min air stream entering the cave from the crane maintenance area and the air stream that infiltrates the storage facility. The cave exhaust air (5000-ft^3/min) passes through the handling cave roughing filters before being discharged to the atmosphere through prefilters, HEPA filters, and the stack. Thermocouples are located in the storage area cooling air inlet and exit plenums, the handling cave cooling air exit plenum, and the stack to monitor the temperature of the inlet and exit air streams continuously.

6.2.1.2 Cask Receiving Area. The cask receiving area may be heated by four unit heaters supplied with steam, identical to those used elsewhere in CPP-603. The heaters are arranged so that the temperature of the receiving area can be kept reasonably comfortable in the winter. Condensate from the unit heaters is discharged to the CPP-603 nonradioactive drain system.

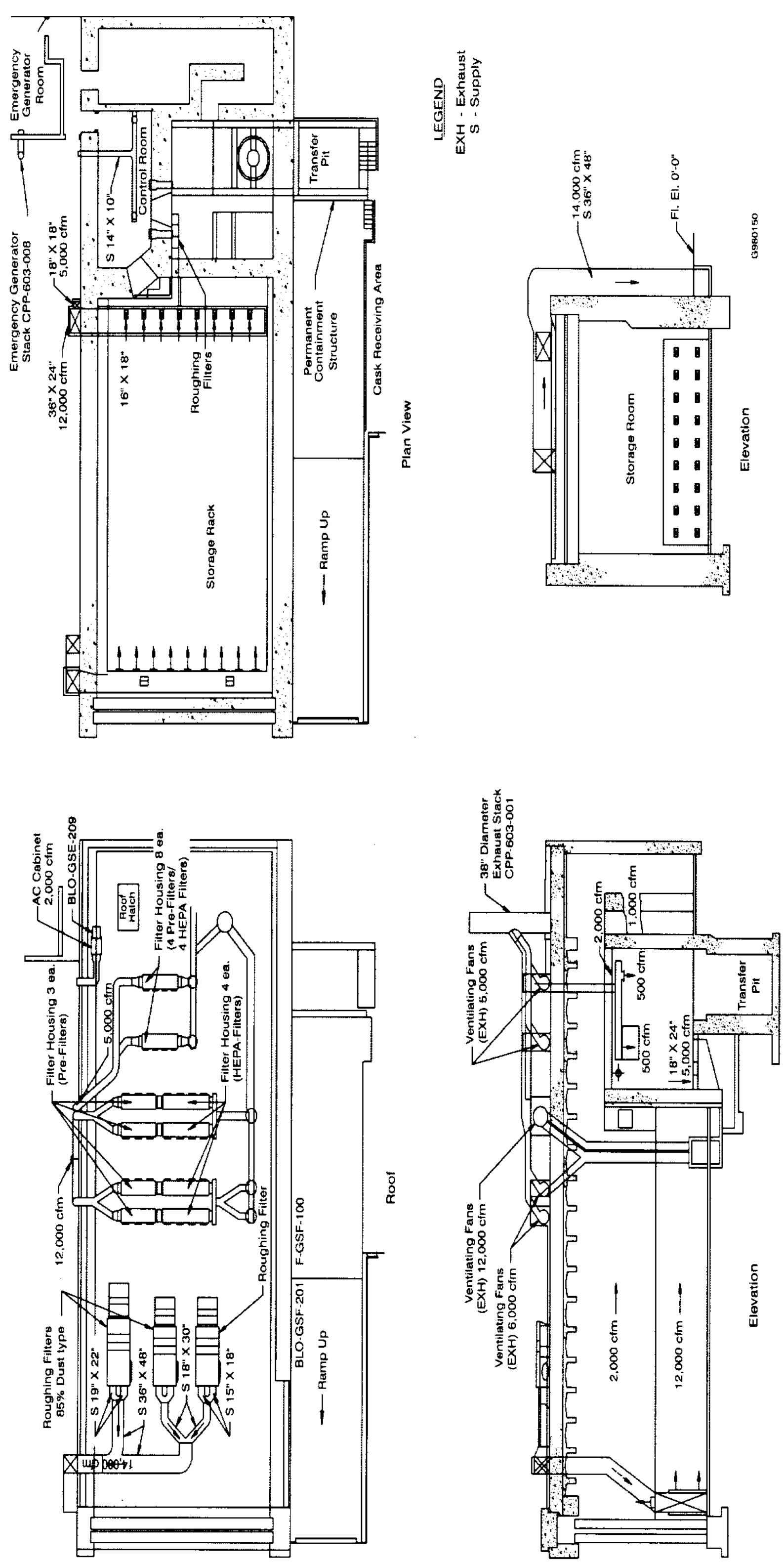

Figure 6-3. Cooling air system.

6.2.2 Filters

Roughing filters, prefilters, and HEPA filters remove particulate from the storage facility cooling air streams. The inlet air streams pass through roughing filters, whereas the exhaust air streams pass through both prefilters and HEPA filters to remove dust and foreign material before the air is discharged to the atmosphere. The prefilters and HEPA filters are enclosed in caisson-type enclosures that permit "bagging out" of individual filters.

The roughing filters and the prefilters are 60% efficient when tested by the National Institute Standards and Technology (NIST) Atmospheric Dust Spot Test. The HEPA filters have a minimum efficiency of 99.9% for particles 0.3 μ in diameter when tested by a DOE-approved test method using a DOE-approved test aerosol. After installation, the HEPA filters are in-place tested. The prefilters are constructed of fire-resistant components and are designed to withstand an air temperature of 250°F (394 K). All the facility filters are replaceable without posing a radiation hazard to maintenance personnel. The cave roughing filter bank, the exhaust air prefilter, and HEPA filter banks are equipped with differential pressure instruments to measure and indicate pressure. If damaged fuel elements are handled, the HEPA filters may require changing on the basis of radiation level rather than pressure drop. Radiation surveys determine whether a change based on radiation level is necessary. The HEPA-filter caissons are provided with upstream and downstream sample ports for in-place filter testing.

6.2.3 Facility Stack

All cooling air from the storage facility is discharged to the atmosphere through a 32-in.-diameter stack located on the storage facility roof. The top of the facility stack is approximately 65 ft abovegrade.

6.2.4 Instrumentation and Controls

The ventilation system is provided with sufficient instrumentation, controls, and alarms to ensure proper and safe operation of the IFSF. The computer-based Fuel Storage Distributed Control System (FDCS), which is located in the control room, is used to monitor, control, and annunciate alarms for the facility (see Subsection 6.2.4.5). Alarms are also annunciated at the FAST control room. The following discusses the instruments and controls associated with the ventilation system.

6.2.4.1 Filter Differential Pressure. The differential pressure across each of the exhaust prefilter and HEPA filter banks (see Figures 4-1 and 4-2) is monitored and displayed on the FDCS. The differential pressure across the three roughing filter banks is not monitored.

6.2.4.2 Facility Differential Pressure. The differential pressures between the fuel storage area and atmosphere and between the control room and atmosphere are monitored and displayed on the FDCS. When operating, the ventilation system maintains a slight negative pressure in the fuel storage area.

6.2.4.3 Cooling Airflow. Flow monitoring instrumentation is provided for the storage area and the cave area exhaust air streams. The full-scale range of the storage area flow is from 0 to 15,000 ft^3/min. The full-scale range of the cave area flow is from 0 to 6000 ft^3/min. Each of these flows can be monitored from a flow computer, a strip chart recorder, or from the FDCS. Low-flow alarms for each area are annunciated on the FDCS.

6.2.4.4 Temperature Monitoring. Thirteen Type-K thermocouples continuously monitor IFSF temperatures, and readouts for each thermocouple are provided on the FDCS. Nine thermocouples, located in the fuel storage area, monitor the surface temperatures of the fuel storage racks and the north and south walls. The other four thermocouples monitor air temperature and are located in the supply air plenum, in the fuel storage area exhaust air plenum, in the fuel handling cave exhaust plenum, and in the stack. A stack high temperature alarm of 170°F (350 K) is annunciated on the FDCS. An out-of service thermocouple may be replaced from outside the building.

6.2.4.5 Ventilation System Design. The ventilation and cooling air for the IFSF is supplied to and exhausted from the facility by four systems: system 1, cave exhaust; system 2, normal supply and exhaust; system 3, first standby; and system 4, second standby.

The normal control system for these ventilation systems is the FDCS. The FDCS consists of an input/output (I/O) computer and a graphical user interface (GUI) computer as described below.

I/O computer

All field connections to the IFSF ventilation systems are through the I/O computer.

The I/O computer controls the ventilation system interlocks and fan startup sequences.

A numeric keypad and digital display are located at the I/O computer to provide a backup operator interface to the GUI computer. Important functions such as startup and shutdown of the ventilation systems can be accomplished from this keypad and display. Access to the control functions requires knowledge of a password.

GUI computer

The GUI computer provides graphical presentation and interface for operating and monitoring the IFSF. Instrument readouts, system status, alarm conditions, messages, etc., are graphically displayed. In addition, control of the IFSF ventilation systems is provided through graphical Hand-Off-Auto switches. Access to the control functions requires knowledge of a password.

Ventilation and cooling air is supplied to and exhausted from the IFSF by the four systems described below. Normal operation of the ventilation system is controlled by the FDCS. However, Hand-Off-Auto switches are located at each fan MCC cubicle to allow operation of the fans in the event that the FDCS fails. In the "Hand" mode the blowers operate with no interlocks or control logic. In the "Auto" mode the fans are controlled by the FDCS. The following describes the normal operation of the four systems with the blower MCC switches set to "Auto".

The control system provides blower operation in accordance with a logic operation that ensures correct sequencing of blower turn-on. The sequencing ensures that exhaust blowers come on before supply blowers and that blowers with correct flow capacities are matched. This logic ensures that the contaminated areas within the IFSF are not pressurized and that cooling airflow will be provided. It is possible for an operator to place the hand switches for all blowers in the "Off" position if operational needs require this. Alarms provide monitoring capability should this be necessary. System status is displayed on the main screen of the operator workstation in the control room. If a Hand-Off-Auto switch is in the "Hand" mode, the blower operates without interlocks or control logic. This allows manual operation of selected blowers if the FDCS were to fail. This could allow operation of a supply blower before an exhaust blower, which could pressurize the facility. Operating procedures require an exhaust blower to be in operation before and during the operation of the corresponding supply blower.

System 1, the cave exhaust, consists of blowers BLO-GSF-207 and BLO-GSF-208, each of which is a 5000-ft^3/min blower. Either may be the normal or the standby blower. Normally only one is operating; however, both may be operated at the same time if necessary. If the selected blower fails to start and run (as evidenced by a pressure indication to the logic) in 10 seconds, the "standby" blower will start. At least one of these blowers must be operating before systems 2, 3, or 4 will start. This is one part of the logic that ensures that the IFSF will not become pressurized during operation in the automatic mode.

System 2 is the primary storage area supply and exhaust system. Blower BLO-GSF-206, a 12,000-ft^3/min exhaust blower, must start and be running (as evidenced by pressure indication to the logic) before blower BLO-GSF-201, the 14,000-ft^3/min supply blower, will attempt to start. System 2 operates only on normal power.

System 3 and system 4 are essentially identical and are the standby storage area supply-exhaust systems. System 3 consists of blower BLO-GSF-202, a 7000-ft^3/min supply blower, and blower BLO-GSF-204, a 6000-ft^3/min exhaust blower. System 4 consists of blower BLO-GSF-203, a 7000 ft^3/min supply blower, and blower, BLO-GSF-205, a 6000 ft^3/min exhaust blower. As in system 2, the supply blowers have a larger capacity than the exhaust blowers because part of the cooling air flowing through the storage area is exhausted by system 1, the cave exhaust, which, along with the system 2, 3, or 4 exhaust blowers, provides higher total exhaust flow to maintain negative pressure.

If standby-system operation is required, the control logic will attempt to start one of the exhaust blowers for the standby systems, systems 3 or 4, first. Ten seconds later, if pressure indication of exhaust blower operation is present, the corresponding supply blower will start. If blower start does not occur, the system will automatically switch to the other standby system, and the logic will repeat.

If standby blower operation is required, normally only one set of standby blowers will start, providing 7000 ft^3/min of cooling air. A full facility (a 1,200,000-Btu/h design heat load) will yield a calculated graphite fuel centerline temperature of approximately 550°F (561 K). With a 7000-ft^3/min airflow, the air exit temperature would be approximately 80°F (45 K) higher than the exit temperature resulting from a 14,000-ft^3/min airflow. Therefore, 7000 ft^3/min is satisfactory for long-term storage. If desired, the second set of standby blowers may be started manually, providing 14,000 ft^3/min of cooling air.

For each system, an alarm on the FDCS will annunciate a failure, and also at the FAST control room.

All the ventilation systems, except system 2, are supplied by both normal and standby power. Thus, upon a loss of normal power, any operating system except system 2 will restart on standby power. If system 2 is operating at the time of a power failure, either system 3 or system 4 will start up, replacing system 2.

Each supply and exhaust duct contains a backdraft damper to prevent closed flow loops through adjacent blowers. As each of the supply and exhaust blowers start and stop, one backdraft damper opens and one closes. In the event of a damper motor failure, a backdraft damper can be quickly disconnected from its drive motor and manually opened to permit flow.

Airflow can stop for up to 22 days without fuel becoming overheated (see Subsection 8.5.4). Therefore, the short time required for standby power to come on line is not significant.

The only operating restriction for the heating and ventilating systems is that which requires an exhaust blower to be placed in operation before the corresponding supply blower to prevent pressurizing the facility.

6.3 Fire Control

The IFSF is constructed entirely of concrete and steel and has thick concrete shielding walls between functional areas. Therefore, the facility itself will not support combustion. Limited amounts of combustible materials are stored in the facility. Combustible properties of the graphite fuels are discussed in Subsection 8.6.2.2. If a fire should occur, for example, in the electrical or control cables, the internal shielding walls will contain the fire in the area where it occurs. Because interaction between areas is highly improbable, the fire potential of each area and the hazards of the fuel itself are considered in this SAR, rather than the potential of an all-consuming facility fire. The fire potential of each operational area is discussed in Subsection 8.4 and the fuel fire hazard is discussed in Subsection 8.4.2.

6.4 Hazardous Chemicals

Currently, fuel handling and storage operations at the IFSF do not require the use of hazardous chemicals. However, should conditions require the use of hazardous chemicals in the facility, an evaluation would be made and controls would be implemented to ensure safe handling and storage, and this SAR and other appropriate authorization basis documents[23] would be revised, if necessary, to envelop such activities.

6.5 Waste Disposal

During normal operations small quantities of gaseous, liquid, and solid waste may be generated at the IFSF fuel storage facility. Where possible, these products are disposed of by existing methods, systems, and equipment. The waste is confined and handled in accordance with applicable INTEC procedures, and any radioactivity released to the environment is done so in accordance with established guidelines. These procedures and guidelines are described in Chapter 9 of Part I of the INTEC SAR.[24]

6.5.1 Gaseous

As previously described, the IFSF exhaust ventilation system is equipped with prefilters and HEPA filters that limit the release of radioactive particulate into the environment. The ventilation system also maintains the exit temperature of the facility's cooling air at an acceptably low level. Normal and abnormal operations related to gaseous discharges from the facility are discussed in Subsection 8.2.

6.5.2 Liquid

Liquid waste may be generated at the IFSF. The possibility exists that the waste might be slightly contaminated. Therefore, all liquid waste streams generated at the fuel storage facility are connected to the existing CPP-603 floor drain system. This system collects all contaminated and potentially contaminated liquid streams in the CPP-603 area and routes them to the hot-waste catch tank that is located just east of CPP-603, VES-SFE-126. From VES-SFE-126, the waste is pumped to the CPP-604 process equipment waste (PEW) evaporator for concentration and eventual calcining and storage.

All nonradioactive liquid waste, primarily condensate from the cask receiving area and from the control room space heaters, flows to the existing CPP-603 noncontaminated waste system. This system collects the noncontaminated waste generated in the CPP-603 area and routes the waste to the waste disposal pit located about 200 ft north of the fuel storage facility.

6.5.3 Solids

Radioactively contaminated solid waste includes ventilation system filters, coveralls, rubber gloves, equipment, and materials used in cleaning and decontamination. Solid waste is segregated, collected, packaged, labeled, and removed via the personnel exit of the crane maintenance area and is handled in accordance with approved INTEC standard methods.

6.6 References

1. G. E. Bingham, R. D. Modrow, and R. S. P'Pool, *Design Criteria for the HTGR Fuel Storage Facility*, Idaho Nuclear Corporation, CI-1214, March 1971.

2. P. E. Wildenborg, letter to S. Wildman, "FSAR for the Irradiated Fuels Storage Facility: Radiation Fields at the Facility Exterior," PEW-3-83, September 14, 1983.

3. R. L. Sant, letter to D. S. Swanson, "A Comparison of the Irradiated Fuel Storage Facility Baseline Source Term to the Foreign Research Reactor Fuel Source Term, " RLS-01-98, June 1, 1998.

4. R. L. Sant, letter to D.S. Swanson, "A Comparison of the Irradiated Fuel Storage Facility Baseline Source Term to the Experimental Breeder Reactor-II Fuel Source Term," RLS-02-98, July 14, 1998.

5. R. D. Sayer, letter to W. A. Kyes, "CPP-603 IFSF PSD Validation Radiation Survey Results," RDS-44-95, December 19, 1995.

6. J. R. Arrowood, letter to M. A. Stubblefield and D. S. Swanson, "INTEC CPP-603 Radiation Survey Results for PSD Validation," JRA-06-98, June 3, 1998.

7. Lockheed Martin Idaho Technologies Company, INEEL Radiological Control Manual.

8. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," Chapter III, "Derived Concentration Guides for Air and Water," U.S. Department of Energy, February 8, 1990.

9. M. A. McKenzie-Carter, letter to E. E. Hochhalter, "Results of AIRDOS-EPA Calculations for the IFSF," MMC-22-89, July 25, 1989.

10. DOE Order 5400.5, p. III-2.

11. S. S. Kim, Minimum Criticality Dose Evaluation of a Neutron Detector in the IFSF, INEL-95/314, May 1996.

12. J. M. Mines, JMM-03-97, and P. J. Sentieri, PJS-04-97, letter to Distribution, "Allowed Fuel Handling Zone in the Cask Receiving Area of the Irradiated Fuel Storage Facility (IFSF)," April 21, 1997.

13. J. W. Sterbentz, *Criticality Alarm System Response to a Criticality Event on the Truck Ramp in the PCS Area*, INEEL/INT-97-01079, September 1997.

14. J. W. Sterbentz and S. S. Kim, *Criticality Alarm System Response to a Criticality in the Cask Receiving Area around the PCS*, INEEL/INT-98-00001, March 1998.

15. S. S. Kim, letter to J. M. Mines, "Effects of PCS Double Walls on Criticality Dose Rate Results," SSK-06-98, May 26, 1998.

16. S. S. Kim, letter to J. M. Mines, "CPP-603 Cask Receiving Area (IFSF) CAS Coverage Zone," SSK-08-98, November 23, 1998.

17. DOE Order 5480.24 "Nuclear Criticality Safety," U.S. Department of Energy, August 12, 1992.

18. J. W. Sterbentz, letter to H. A. Worle and J. T. Taylor, "Dose Estimate for a Criticality Event in the IFSF Storage Area," JWS-11-97, July 1, 1997.

19. J. W. Sterbentz, letter to T. N. Chriswell, "Final SNF Dose Rate Results for the IFSF CAS," JWS-16-97, October 9, 1997.

20. S. S. Kim, letter to S. E. Holaday, "Detector Dose Rate Results for BMI-Spec, WAPD, and TRIGA-Al Fuel Movements in the IFSF," SSK-03-98, March 5, 1998.

21. P. J. Sentieri, *Criticality Safety Evaluation for Various Fuels Proposed for Dry Canning*, INEL-95/306, April 1996.

22. K. B. Woods, letter to F. T. Wilkins, Storage of Splayed Aluminum Fuels in the IFSF, KBW-05-97, October 7, 1997.

23. PSD, Section 15, Technical Standards, 4.12 Series.

24. INTEC SAR, Part I, "General Safety Analysis," Chapter 9, "Radioactive and Hazardous Waste Management."

7. FACILITY OPERATIONS

CONTENTS

FIGURES

7. FACILITY OPERATIONS

Fuels and other fissile materials requiring dry storage are received at the IFSF in fuel shipping packages, casks, and chargers. The Peach Bottom cask safety analysis is contained in Addendum J to PSD Section 4.5.[1] The Fort St. Vrain and Naval Reactor Bettis Knolls Atomic Power Laboratory (KAPL) (NRBK) casks are not INTEC casks, and the cask owners are responsible for the safety analysis reports for packaging (SARPs) for the two casks. The high-load charger is used for transferring fuels from the CPP-603 FSB to the IFSF. The safety analysis for the charger is contained in Addendum A to PSD Section 4.5.[2] ARMF and CFRMF fuels are shipped from the Test Reactor Area (TRA) of the INEEL in the ATR cask. Use of the ATR cask outside of the INTEC boundary is enveloped by a transport plan, and within the INTEC Boundary by Addendum M to PSD Section 4.5.[3,4] Rover UBM cans are shipped to the IFSF in 110 gallon 6M drums with 2R inner containers; the Rover UBM 6M drums are approximately 70 in. long with a 24 in. diameter. The Rover UBM 6M drums may also be used for transfer of Rover fuel. The 2R liner container is 58 in. long and has a 5.25 in. inside diameter. Other casks or shipping packages that may be proposed for use will be evaluated.

Casks and most other transfer containers are transported by truck or other vehicle. The 60-ton crane, CRN-SF-001, is used to move the transfer container from the vehicle or the high-load charger from the CPP-603 FSB to the IFSF. At the IFSF receiving dock, the casks are removed from the transport vehicle, positioned in the cask transfer car, and moved into the fuel handling cave.

For Rover UBM, up to two buckets (BU-GSF-911), which fill one storage canister, are placed in the insert adapter (ADP-GSF-3) for Rover UBM in the transfer car. A drum containing one Rover UBM can is opened in a drum staging area in the cask transfer area. The can is removed and brought into the PCS, where it is placed in a bucket. See Figures 7-1 and 7-2. This process continues until the one or two buckets are loaded. The transfer car is then moved into the fuel handling cave with the loaded Rover UBM buckets.

In the cave, fuel is transferred from the shipping cask to fuel storage canisters. Some contact–handleable fuels/fissile materials (e.g., Rover fuel, Rover UBM) are transferred from the Rover UBM insert adapter, or other rack/holder, in the transfer car to storage canisters. Fuels processed in the Fuel Canning Station are loaded into the storage canisters, which are typically located in the canning station. The canisters are subsequently positioned in a shuttle bin for transfer to the storage area. Within the fuel storage area, the 10-ton crane, CRN-GSF-101, is used to remove the canisters from the shuttle bin and to insert them into a predetermined position in the storage rack. The sequence would be reversed for removing fuel from storage for transfer to another facility.

For most fuels, the entire operation, except for the placement of a cask into the transfer car outside of the cave, is performed remotely within shielded operating areas. Cask decontamination, if needed, can be done in the PCS. Subsection 7.1 provides a detailed discussion of the handling and storage procedures used for fuels currently in storage at the IFSF.

7.1 Fuel Handling Sequence

Fuels to be stored in the IFSF are transferred by transfer container (e.g., cask, charger or drum) to the cask receiving area (except when unirradiated Rover fuel is transferred). The container is generally transferred either by truck or, when fuel is received from the CPP-603 FSB, by the 60-ton crane, CRN-SF-001. The crane then is used to move the container into the PCS. Typically, the transfer container is then positioned in the cask transfer car (see Figure 7-3). The container top-head closure bolts, if applicable, are removed and the container is prepared for unloading. For some fuels, if the cask

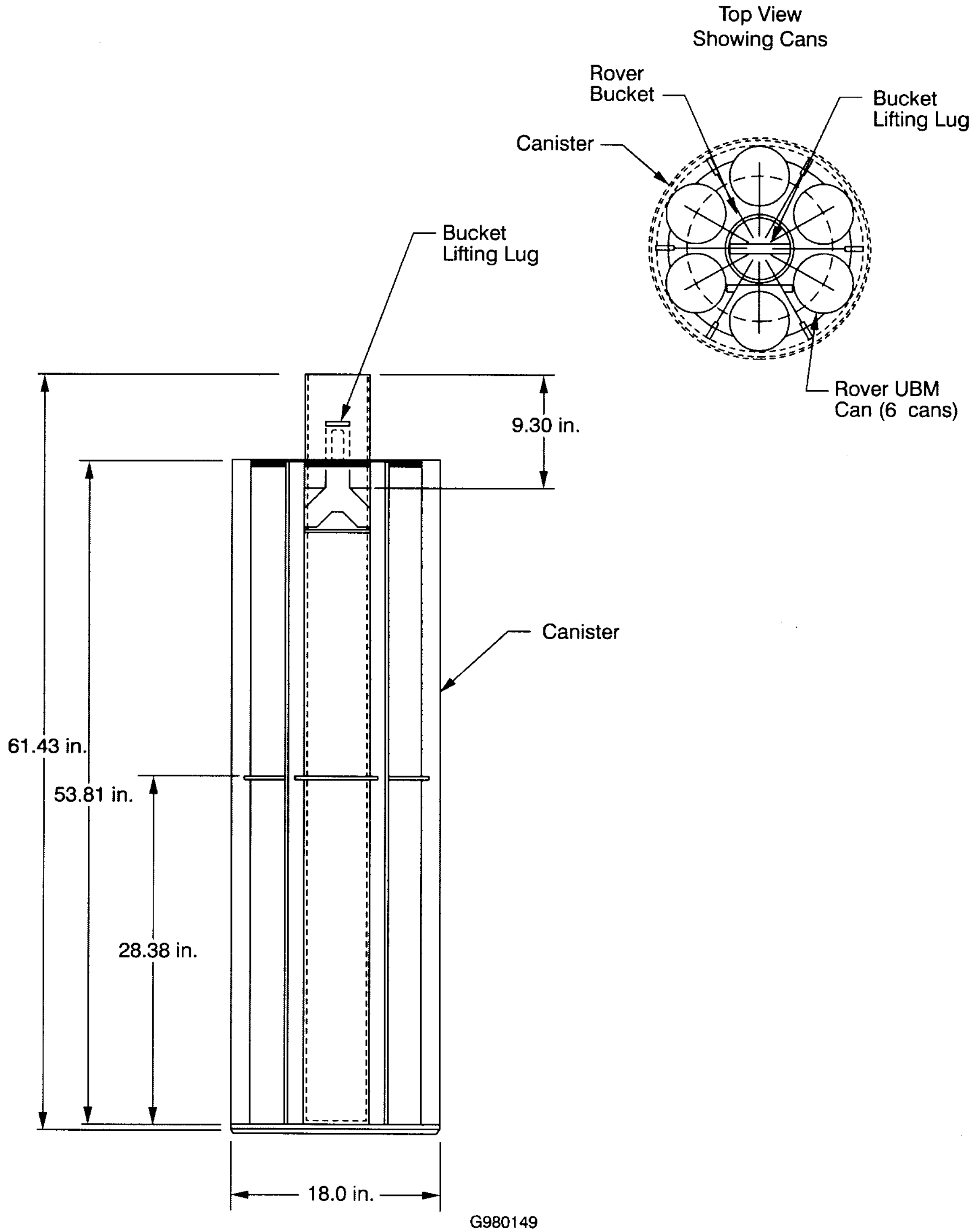

Figure 7-1. Rover UBM Bucket (BU-GSF-911-xx) (Unique bucket identifier denoted by xx).

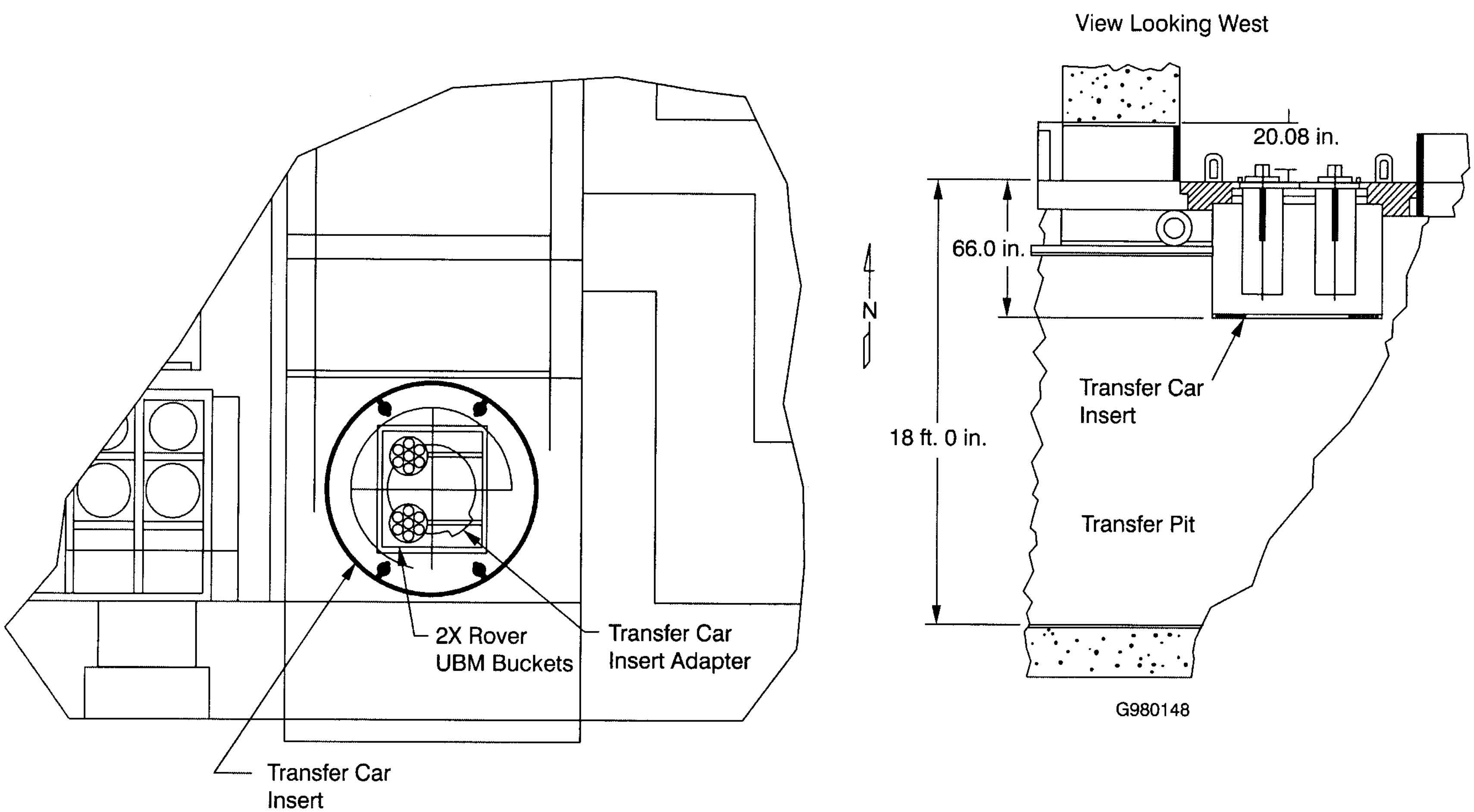

Figure 7-2. Rover UBM Transfer Car Insert Adapter (ADP-GSF-3) shown in transfer car.

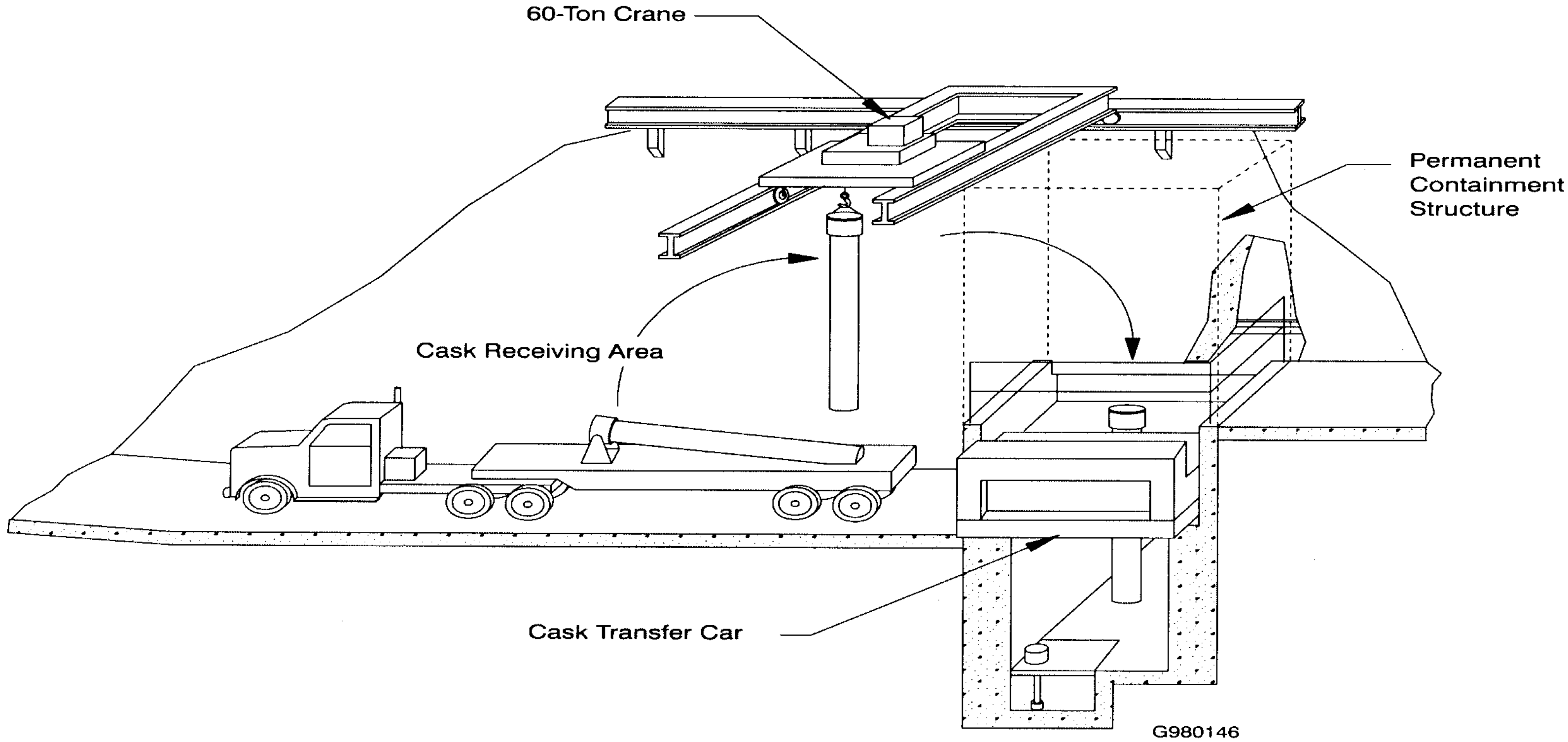

Figure 7-3. Transferring fuel shipping cask.

is suspected of carrying damaged elements, a judgment is made at that time concerning the disposition of the cask and fuel. In most cases, the cask will be accepted, and damaged fuel elements will be stored. For details of handling unirradiated Rover fuel in the cask receiving area, see Addendum A to this SAR.

Normally, for Rover UBM, a sufficient number of Rover UBM cans to fill one storage canister is staged near the PCS with each can still in its 6M drum. Up to two Rover UBM buckets are initially placed in the Rover UBM insert adapter in the transfer car. If one bucket is placed in the adapter, a cover is placed over the second bucket port in the adapter. A drum containing one Rover UBM can is opened, the can is removed, attached to the crane, and moved into one of the buckets in the cask transfer car in the PCS. The process continues until the buckets have been filled. The criticality safety of the array of 6M drums is ensured by adherence to the criticality safety transport index rule.[5,6] The 6M drum packaging provides approximately 8 in. spacing between its contents and any other fissile material. A criticality safety evaluation[7] has shown that an array of 72 cans (not in drums) of Rover UBM is critically safe when dry as long as a minimum spacing of 3.75 in. is maintained between the array cans. Therefore, when a single Rover UBM 6M drum is opened and its Rover UBM can is removed, the 6M drum array is still critically safe with that can in the vicinity of the array. The 6M drum array is critically safe even if a Rover UBM can is dropped on top of the 6M drum array, as this is a less reactive arrangement than several (dry) scenarios involving Rover UBM cans. (See Reference.) Therefore, the removal of one Rover UBM can from its drum within the array does not present a credible criticality risk. When not in closed shipping/transfer containers, both Rover fuel and Rover UBM are handled in the CAS coverage zone. Up to 12 Rover UBM cans which have been removed from the drum array outside the PCS and placed in up to two buckets in the transfer car inside the PCS form a critically safe configuration and do not require further separation from any remaining Rover UBM cans in the drum array.

The cask, other container, or pair of Rover UBM buckets is moved into the handling cave on the transfer car. The lid is removed (if applicable), and the fuel elements and container, or another packaging unit (fuel basket, bucket, etc.), are removed and placed in a canister in a floor well, the canning station, or directly in a floor well (no canister) to await further handling. If applicable, the cask lid is replaced and the cask is removed from the handling cave and returned to the point of origin. A typical fuel unloading operation is illustrated in Figure 7-4.

Following cask removal, the fuel is removed from the handling cave floor well and placed directly into the canister (see Figure 7-5). For some fuels, configuration control is necessary. For these, an insert is installed in the canister.

The transfer of fuels to the canning station and the handling of fuel in canning station operations are described in Addendum B to this SAR.

When a storage canister is filled with fuel, the lid is placed on the canister and latched. Using the 10-ton crane, CRN-GSF-101, or the 2-ton hoist, CRN-GSF-401, the canister is then (1) placed into the shuttle bin, (2) transferred to the storage area, and (3) placed into the selected storage rack position indicated on the appropriate transfer documentation. The operation is illustrated in Figure 7-6.

Fuel storage canister positions in the storage rack are recorded in accordance with accountability requirements. The location of each fuel element and each storage canister is recorded by element (storage can or tube), canister number, and storage rack row and position number. Previously, any arrangement of fuel storage canisters approved for storage in the IFSF was critically safe in the storage rack, so that the specific position of individual fuel storage canisters was not a safety requirement. However, the addition of an increasing quantity and variety of fuels and other fissile material potentially increases the total array reactivity sufficiently for restrictions to be required as to which specific positions loaded fuel canisters

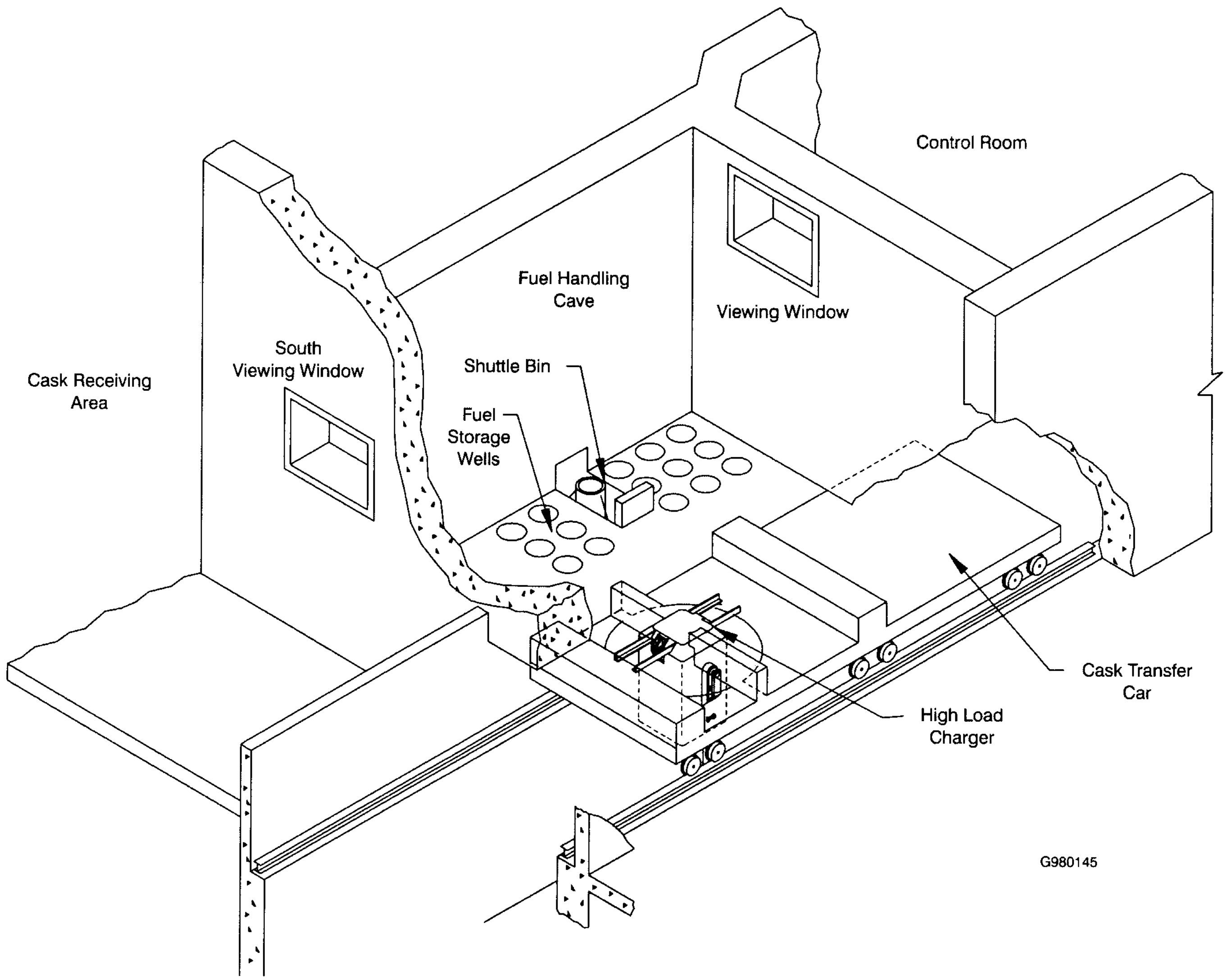

Figure 7-4. Unloading fuel shipping cask.

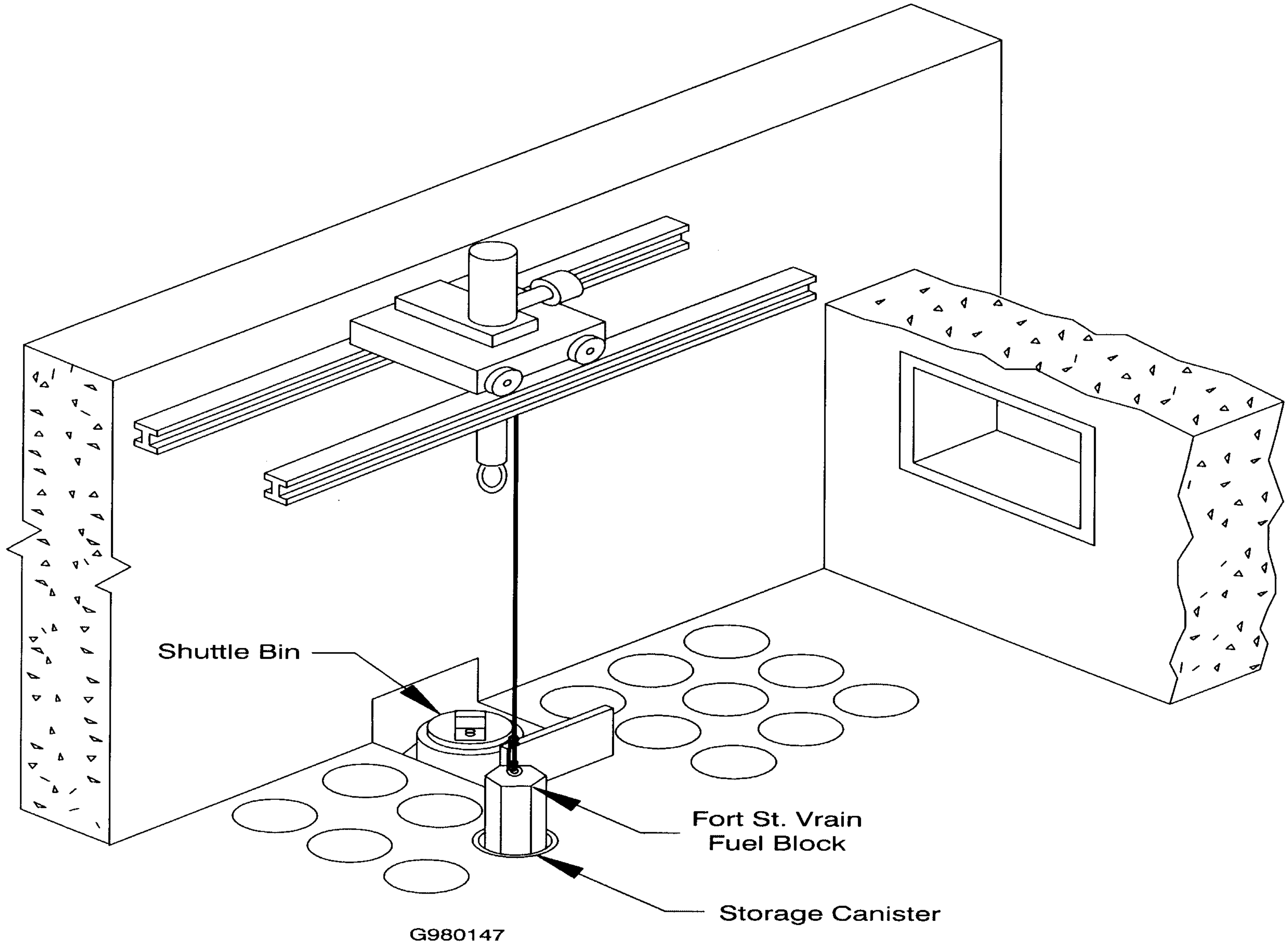

Figure 7-5. Placing Fort St. Vrain fuel in a storage canister.

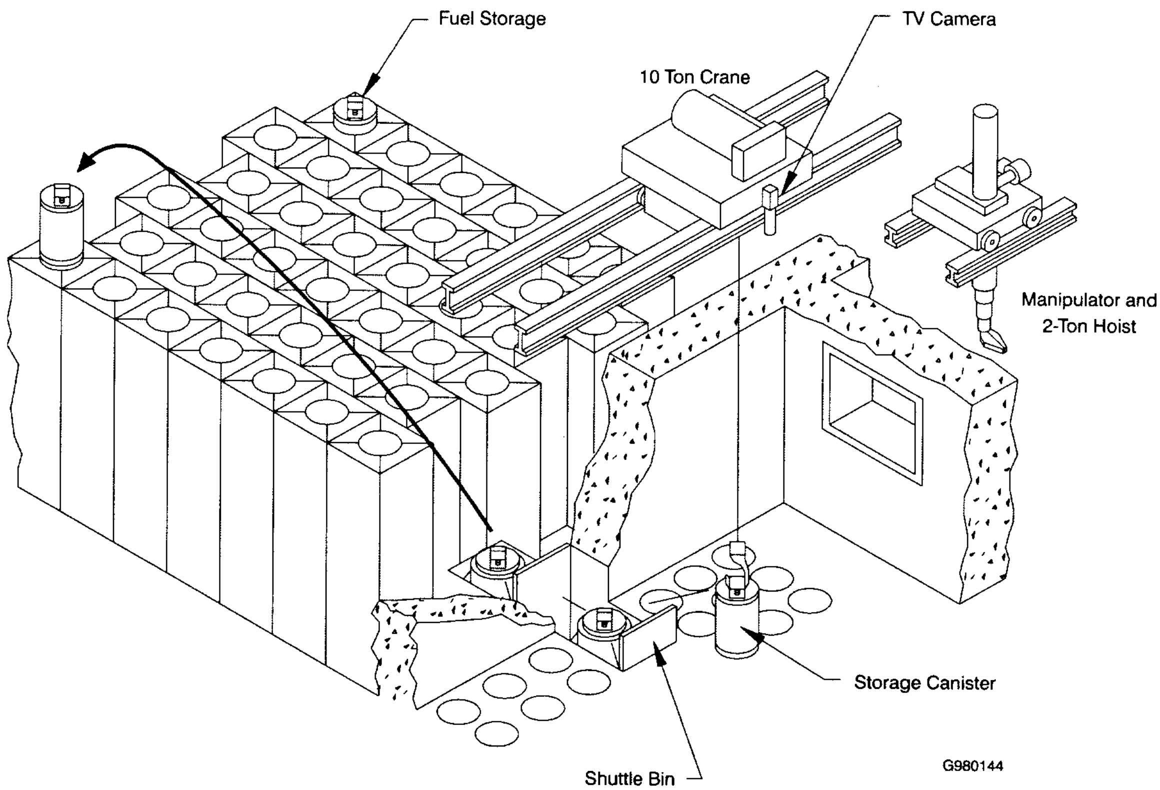

Figure 7-6. Placing storage canisters into the storage rack.

may occupy relative to other canisters containing fissile material. See Section 7.2 and Technical Standard (TS) 4.12A1. It should be noted that several of the most reactive fuel-loaded storage canisters must be in storage area positions different from the mapped configuration before criticality safety of the storage array could be compromised.[8]

The retrieval of fuel from storage, placing the fuel into a cask or other transfer container, and the removal of the loaded container from the facility are essentially the reverse of the above. Fuels/fissile material which may be handled in the CAS coverage zone of the cask receiving area, and/or which may be packaged in other approved transfer containers (e.g., 6M drum), may also be retrieved and removed from the facility by reversing the handling sequence specific to that fuel or material.

It should also be noted that Rover (Parka) fuel may be repackaged from cardboard tubes into metal tubes of the same nominal dimensions. Rover fuel in metal tubes is not more reactive than the same fuel in cardboard tubes.[9] Therefore, any criticality or other safety evaluations which assume the fuel is in cardboard tubes will envelop the same configurations and fuel contents in metal tubes. End plugs of metal tubes may contain rubber.[6]

If not repackaging as a reversal of the handling sequence described in Addendum A to this SAR, Rover fuel will be repackaged and removed from the facility as enumerated below.

1. The transfer car is fitted with the high load charger insert (INRT-GSF-2), the Rover UBM insert adapter (ADP-GSF-3), and one or two special Rover fuel tube transfer devices (TD-GSF-928-1 and/or TD-GSF-928-2). The fuel tube transfer devices (Figure 7-7) are placed in the Rover UBM insert adapter. If a fuel tube transfer device is not placed in a port, a special cover plate (COV-GSF-906) is placed in the bottom of that port to prevent any fuel tube from dropping through the drain hole in the port bottom. The transfer car and a Rover fuel canister are staged in the fuel handling cave;

2. One fuel canister insert is removed from the canister. Up to 15 Rover fuel tubes, each containing the fissile equivalent of up to 4 Rover fuel rods, (maximum of 120 g ^{235}U per rod, maximum of 480 g ^{235}U per tube), are removed, one-at-a time, and placed into a Rover fuel tube transfer device in the transfer car. Each Rover fuel transfer device holds at most 8 Rover fuel tubes. Before the tube is placed into the transfer device, the inner and outer cardboard tubes may be removed and the fuel contents repackaged into a metal tube (TUB-GSF-XXX, where XXX is a unique 3 digit number for each tube);

3. The transfer car is moved into the PCS, and one tube is removed from the transfer car and out of the PCS to the CAS coverage zone. If repackaging was not done in the cave at step 2 above, a repackaging area may be set up adjacent to the PCS. In the repackaging area, the inner and outer cardboard tubes may be removed and the fuel contents then repackaged into a metal tube (TUB-GSF-XXX);

4. The tube is placed into a 6M drum;

5. The process is repeated until the drum is filled with up to four tubes, and the drum is closed;

6. The previous steps are repeated until up to 6 drums are loaded and closed. Note that up to five closed, filled Rover fuel drums are allowed next to the open drum while the open drum is being filled with up to 4 Rover fuel tubes.

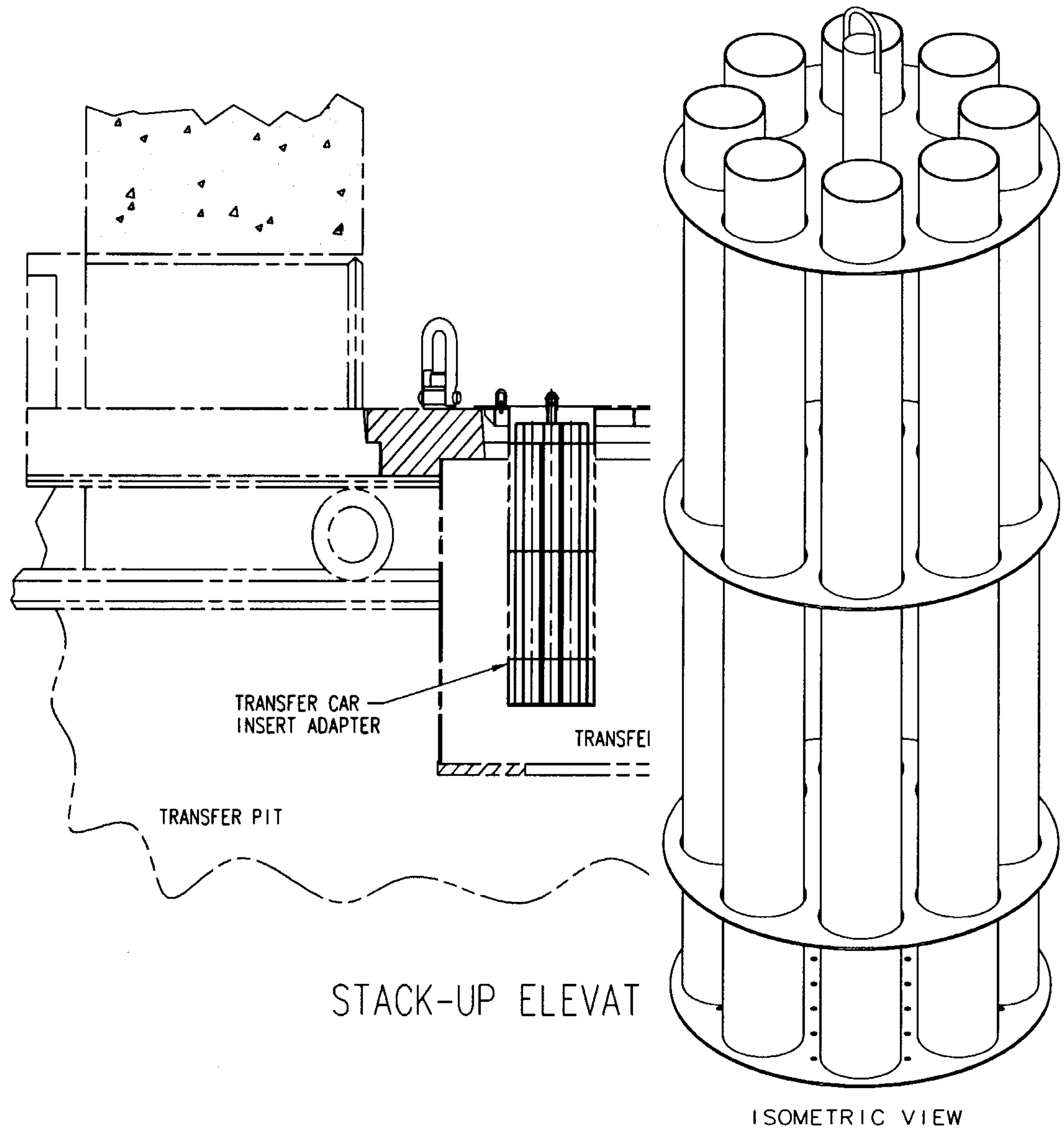

Figure 7-7. Rover fuel tube transfer device (TD-GSF-928-X).

7. The filled, closed drums are removed at least 20 feet from the repackaging area before further fuel handling may take place there.

If all or part of the contents of any Rover fuel tube falls out of a cardboard tube, it shall be returned to an undamaged Rover fuel tube (cardboard or metal) before the fuel handling operations resume in the affected area (cave or CAS coverage zone/PCS).

7.2 Storage Mode

The storage mode for each fuel is based on criticality calculations that determine (1) the mass of fissionable material permitted in each canister, (2) the critically safe configuration within the canister, and (3) the criticality safety of the storage rack array. The approved configurations for storage of each approved fuel type are listed in Technical Standard (TS) 4.12A1.[10] The restrictions on all fuel storage positions are also listed in TS 4.12A1.

7.3 References

1. PSD 4.5J, "Peach Bottom Cask."

2. PSD 4.5A, "The High-Load Charger."

3. PSD 4.5M, "Operational Safety Basis Review for ATR Spent Fuel Element Transfer Cask Operations at the ICPP."

4. PSD 4.5M-Sup, "ARMF and CFRMF Fuel in ATR Cask."

5. 49 CFR 173.417, "Authorized Fissile Material Packages," Code of Federal Regulations, Office of the Federal Register.

6. 10 CFR 71.59, "Standard for Arrays of Fissile Material Packages," Code of Federal Regulations, Office of the Federal Register.

7. Lockheed Martin Idaho Technologies Company, *Criticality Safety Evaluation for UBM Can Filling and Storage Operations in the Rover Dry Process Cells*, INEL-96/074, March 1996.

8. K. B. Woods, *Criticality Safety Evalation for Mapped Array in the Irradiated Fuel Storage Facility*, INEL/INT-97-0079, April 1997.

9. K. B. Woods, *Criticality Safety Evaluation for Rover Parka Fuel,* INEEL/INT-98-00978, March 1999.

10. PSD, Section 15, Technical Standards, 4.12 Series.

8. SAFETY ANALYSIS

CONTENTS

FIGURE

TABLES

8. SAFETY ANALYSIS

Fuel stored in the IFSF may contain large amounts of fission products, highly enriched uranium, and graphite. System design is evaluated in this section as it relates to safety during normal operations and foreseeable abnormal events, actions, and conditions. Various hazards that may occur are identified and described. Particular attention has been paid to potential hazards of nuclear criticality, breach of confinement that could result in radiation exposure or radioactivity release, fire and explosion, and chemical and industrial hazards. Operating requirements and opportunities for human interaction are assessed to determine the potential for cause or prevention of undesirable events.

DOE Order 5480.24 requires nuclear facility process and storage designs to incorporate safeguards that require at least two independent, unlikely, and concurrent changes to occur in either process or storage conditions before a nuclear criticality is possible, which is the double-contingency principle. Protection shall be provided by either (1) the control of two independent process parameters, which is the preferred approach, or (2) a system of multiple controls on a single parameter.

This safety analysis was conducted to assess the adequacy of equipment and processing procedures for the IFSF. The consequences of equipment failures and operational errors were evaluated to postulate the maximum accident in the IFSF, against which the design adequacy of the IFSF is evaluated. The radiological consequences of that accident and of normal operations of IFSF were determined.

The results of the safety evaluation are presented under the subheadings of this section. This evaluation demonstrates that the facility design features and controls reduce the residual risk of facility operations to an acceptably low value. The processes and storage in the IFSF satisfy safety criteria under both normal and abnormal operating conditions. Though no likely cause for a serious accident in the IFSF was identified, a nuclear excursion in one of the shielded areas was chosen for evaluation of the system for maximum potential undesirable effects.

8.1 Natural Phenomena

Chapter 1 of Part I of the INTEC SAR discusses INTEC site characteristics as well as natural phenomena and their respective impacts on the safe operation of the INTEC and consequently, the IFSF. The discussion covers meteorology, hydrology, seismology, geology, volcanism, population distribution, land and water use, and associated site activities as they relate to the INEEL and INTEC. The criteria used to determine the design bases and structural requirements for INTEC facilities are the maximum postulated off-site effects of normal and off-normal operations given the site characteristics.

8.1.1 Earthquake

Since the original design of the IFSF in 1971, there have been several seismic analyses performed on the structure and components of the IFSF. In 1996, three seismic analyses were performed to provide a comprehensive and current evaluation basis for the facility and to characterize the conformance of the facility, rack, and storage canisters to current seismic design criteria. Strictly speaking, the seismic event against which an existing facility is evaluated is an evaluation basis earthquake. However, commonly accepted practice in DOE Safety Analysis Reports is to refer to seismic events as a design basis earthquake (DBE), even for existing facilities. This practice will be adhered to in this document.

One of the analyses performed in 1996 covers the building structure and its vital components, excluding the storage area rack and canisters.[1]

Another analysis covers the storage rack.[2] The third analysis covers the storage canisters.[3] The analysis in Reference 1 indicated some structural deficiencies existed that could be remedied by the addition of a new permanent west wall to the facility (see Subsection 3.3.7). Additional analyses have been performed that include the effects of this building modification.[4] The analyses in Reference 4 build upon and partially supersede those reported in Reference 1.

The seismic analyses were performed in accordance with the DOE-ID Architectural Engineering Standards,[5] and the DOE natural phenomena standard, DOE-STD-1020-94.[6] In accordance with Reference 6, the IFSF has been determined to be a Performance Category 3 structure.

The storage rack analysis[2] shows that the storage rack (in the storage area of the IFSF) meets seismic acceptance criteria. Of particular interest for criticality safety, is that the average canister center-to-center spacing will not be reduced significantly (much less than 0.1 in) by the DBE from its original design value of 24 in. Criticality analyses for fuel stored in the storage area rack generally assume a center-to-center spacing of 22.5 in. for the stored canisters to account for both seismic disruptions and manufacturing uncertainties.

The storage area rack is constructed of A36 steel and air-intake temperatures at the west end of the rack are occasionally significantly below freezing. These factors have raised a concern about the possibility of rack members or welds undergoing brittle fracture, if a DBE should coincide with very cold environmental conditions. A study has been performed to assess the probability and possible effects of such a coincidence.[7] The study consisted of (1) a brittle fracture assessment on the IFSF storage rack structure to estimate a threshold temperature for the rack above which brittle fracture would not be expected to occur in the event of an earthquake, (2) an investigation into the temperature history for the INEEL and the storage rack to estimate how much time the minimum rack temperature is at or below this threshold temperature, and (3) a stress analysis on the rack structure, whereby selected connections in the rack were assumed to fail due to brittle fracture to assess the consequences of such failures. Results of the brittle-fracture assessment indicate that brittle fracture in the rack is not expected to occur for rack temperature above 0°F. The study into the IFSF temperature history shows that the minimum rack temperature is at or below 0°F less than 2.5% of the year.[7] Thus, the probability is very small that a DBE could coincide with the low temperature conditions where brittle fracture is a concern. Even if such a coincidence were to occur, the stress analysis shows that, assuming a conservatively large number of weld failures, there would be essentially no effect on the structural response of the rack.

In the course of investigating the potential for brittle fracture of the storage area rack, other components of the IFSF (such as fuel handling cave floor well racks, shuttle bin, shield doors, cranes) were also considered.[8] No additional safety concerns connected with this issue were discovered. For all components thus considered, the probability of a coincidence of low temperatures and a DBE event is lower than it is for the storage area rack. This is because these components are not exposed to temperatures as cold as is possible near the air intake plenum of the storage area rack. Therefore, no operating restrictions or physical modifications are required.

The rack analysis[2] indicates that the DBE could provide the motive force to let two rows of canisters swing toward each other in pendulum fashion (without any damage to the rack). This motion could bring the bottoms of two adjacent canisters closer together than 22.5 in. An evaluation was made of this effect,[9] showing that the effect on reactivity caused by the small localized variance is within the statistical uncertainty of criticality calculations performed for the IFSF. It has been determined that reduced canister spacing from the DBE could not cause an accidental criticality. Also, the very small predicted rack deformations will not affect decay heat removal from the canisters.

The canister analysis[3] shows that the canisters maintain their ability to retain their contents during and after a DBE. In all cases, the DBE-induced stresses and deflections meet or are within the allowable values.

The facility analysis[4] presents results of the analysis of the major structural features that form the primary load-path of the facility, such as the outside walls and roof, as well as the interior walls and many components of the facility that are important to its operation.

The analyses in Reference 4 show that the addition of the full-height shear wall at the west end of the facility has successfully addressed the structural problems identified in Reference 1. The strength and stiffness of the west end of the building have been greatly improved over the original moment frame design. All primary building structure components satisfy seismic acceptance criteria.

The following equipment and component items were also assessed for the effects of the seismic loading:

1. Cranes CRN-GSF-101 and CRN-GSF-401
2. shuttle bin support steel walls
3. temporary west wall panels
4. shield windows
5. lightweight door panels (access to storage area lighting)
6. shield wall plug
7. cave area shield plate (covering the north end of the transfer car pit)
8. ventilation system mounted on the roof (including the stack)
9. shielding door support structure (inside the building)
10. shielding door support housing (outside the building)
11. crane swing rail
12. fuel shuttle bin
13. cask transfer car
14. fuel handling cave storage racks and wells, with all wells assumed filled with the maximum-weight canister and the fuel canning station.

Items 1-9 were found to meet the acceptance criteria outright. The trolleys of cranes CRN-GSF-101 and CRN-GSF-401 might experience upward accelerations that exceed gravity, but are equipped with restraining brackets to prevent uplift.

For Items 10-14, the following considerations were made to disposition them:

10. The maximum D/C value for the shielding door support housing was projected to be 1.94. Damage to the door housing would affect the ability to open or close the shield door, but could be repaired without any significant impact to facility operations, because the door housing is external to the IFSF building.

11. The crane swing rail was found in Reference 1 to be inadequate for a deadweight of 15 ton on the crane hook and a weight limit of 7 ton was recommended for passing over the swing rail. In fact, the largest load on the hook of crane CRN-GSF-101 in this area is a 2,000-lb-canister. The swing rail is adequate for this load. Nevertheless, to limit risk exposure during the DBE, the cranes should be parked, when not in operation, such that a bridge wheel does not rest on the swing rail.

12. The highest D/C value for the fuel shuttle bin was projected to be 3.75. This occurs for the vertical shield cross-brace. Damage to the shield bracing could lead to a bad fit of the vertical shield against the shield wall, but this would be repairable. Damage to the shuttle bin would have operational, but not safety consequences to on- or off-site personnel.

13. The maximum projected D/C value for the cask transfer car was found to be 1.82 at the rail anchorage. The underlying concrete would continue to support the transfer car. Again, the damage is repairable and no safety consequences to on- or off-site personnel would result.

14. An additional analysis[10] of the cave racks beyond those in References 1 and 4 has been performed. It indicates that the structural welds and members of the fuel handling cave south floor well racks satisfy the seismic acceptance criteria. This means that fissile material in any of the six floor wells (Wells 10 through 15, including the Fuel Canning Station in Well 13) will remain in the floor well and the floor wells will maintain their designed spacing during and after the DBE. However, the north floor well rack is not seismically qualified due to the absence from the design drawings of the base welds that anchor the columns of the north racks to the floor. Pending verification of these welds, temporary storage of fissile material in the north rack (Wells 1 through 9) is limited to a single fuel handling unit (FHU). Any FHU is inherently safe from a criticality accident if it were dropped and spilled from its container (Subsection 8.6.1.4).

It should be noted that in almost every case discussed above, an equipment item must be either in its most vulnerable position or carrying the greatest anticipated load while the DBE seismic loads are being imposed for the item to be significantly damaged (such as when the crane bridge has one wheel on the swing rail, the cask transfer car carries a 60-ton cask, or the shuttle bin carries a maximum weight canister and is nearly fully extended but with the shield panel not flush against the shield wall). It is extremely unlikely that a DBE would occur while these worst-case conditions exist. The IFSF is primarily a storage facility, where handling operations take place relatively infrequently and for short durations. A conservative assumption is that the transfer car, the shuttle bin, or the crane are in operation 200 hours in a year. The probability of a failure caused by the occurrence of an earthquake in excess of the DBE at the INEEL is on the order of 10^{-4} per year. The probability of the seismic Performance Category 3 (PC-3) DBE to occur while the equipment listed in Items 10-14 above is in operation is near the incredible event frequency of 10^{-6}.

The transfer car itself is covered by the analyses discussed above, but other load-supporting equipment used with it is not. To enable remote lid and fuel removal from a cask or charger in the cave, lid bolts are removed from a cask/charger after it is placed in the transfer car within the PCS. The lid is then removed inside the cave. If a design basis earthquake (DBE) should occur during the time a loaded cask/charger is in the transfer car, the contents could possibly spill out unless the equipment supporting the cask/charger in the transfer car was capable of withstanding the DBE, as is the car itself. To preclude unevaluated accident scenarios or accident consequences during a DBE, load-supporting components that are used with the transfer car must be qualified at a PC-3 level before they are used with the transfer car to support fissile material loads, unless the load consists of less than the minimum critical quantity of fissile material under its most reactive credible form and conditions. This ensures against a criticality accident hazard caused by a DBE-related spill of the load onto the floor of the transfer car pit. Doses from other radioactive material are not anticipated to exceed TS limits if spilled during a seismic event, due to associated dose rates and stay times. Table 8-1 lists the load path components that have been seismically qualified.

Adherence to the requirements presented in this discussion will ensure that the DBE will cause only limited operational damage to some equipment in the IFSF, and that (subject to the restrictions imposed on the use of this equipment as discussed above) this potential damage will not cause injury or excessive radiation exposure to operating personnel, co-located workers, or the public.

8.1.2 Wind

Loads on the IFSF facility caused by high winds were calculated in the 1996 facility analysis [1] in accordance with the following guidance given in DOE Standard DOE-STD-1020-94:

1. The maximum straight wind magnitude is 84 mph for Performance Category 3 facilities at the INEEL. The probability of the wind magnitude exceeding 84 mph is 1 x 10^{-3} per year.

2. Tornadoes are not considered a viable hazard at the INEEL. For any facility at the INEEL, the probability for a tornado to exceed the maximum straight wind magnitude of 84 mph is less than 1 x 10^{-6} per year.

3. The maximum height above ground for which missile damage has to be considered is 30 ft.

The building and roof-mounted ventilation equipment will withstand the evaluation basis wind loads without damage. The roof of the facility is high enough that missile damage to roof-mounted equipment need not be considered. However, missile damage may occur to the ventilation ducting on the outside of the north wall and to the shield door enclosure, possibly impacting proper operation of these components. It is expected that any damage can be readily repaired. The time requirement for restoring operability of the shield door is based on operational, not safety, concerns. For the ventilation system, a maximum allowable outage time of 22 days is specified (see Subsection 8.2). This is considered ample time to repair any missile damage to the ducting.

8.1.3 Flood

The combination of local climate, relief, and geology provides the INEEL with favorable natural flood-regulating characteristics. Details of these characteristics are found in Chapter 1 of Part I of the INTEC SAR. There is a flood diversion structure that takes advantage of the natural topographic features of the local area to provide an additional reserve storage space and infiltration area to control floodwater.

The INEEL is located approximately 45 miles southeast and downstream from the Mackay Dam, which impounds a 44,500 acre-ft reservoir on the Big Lost River.

Table 8-1. Summary of seismically and drop qualified loads allowed in the IFSF transfer car.[a]

Case #	Transfer Car Insert	Additional Load-Supporting Equipment	Fissile Material Container	Explanatory Comments	Structural Analyses References	Approval Status[b]
1.	INRT-GSF-2	None	High-Load Charger OR STR Charger OR ATR Cask	INRT-GSF-2 has been seismically qualified for a load up to 120,000 lb (60 tons) that is supported by the bottom plate of insert INRT-GSF-2.	11	Not Approved
2.	INRT-GSF-2	Insert Adapter ADP-GSF-3	Rover UBM Bucket BU-GSF-911	ADP-GSF-3 has been qualified for a load of up to 1,500 lb in each of the two adapter ports. This envelops BU-GSF-911 maximally loaded with 6 Rover UBM cans.	11	Approved
3.	INRT-GSF-2	Insert Adapter ADP-GSF-3	Rover Fuel Tube Transfer Device TD-GSF-928-X	ADP-GSF-3 has been qualified for a load of up to 1,500 lb in each of the two adapter ports. This envelops TD-GSF-928-X maximally loaded with 8 Rover fuel tubes.	11	Approved
4.	INRT-GSF-2	Sliding Saddle SADL-GSF-901-X	GNS 16 Cask	None	12	Not Approved
5.	INRT-GSF-2	Adapter INRT-GSF-4	HFEF-6 Cask	The HFEF-6 cask bottom rests on the bottom plate of INRT-GSF-4. Safety analysis is presented in PSD 4.12, Addendum I.	13	Approved

Table 8-1. (continued).

Case #	Transfer Car Insert	Additional Load-Supporting Equipment	Fissile Material Container	Explanatory Comments	Structural Analyses References	Approval Status[b]
6.	TD-GSF-904	INRT-GSF-27 TD-GSF-905	TN-FSV Cask	The support configuration of INRT-GSF-27, TD-GSF-904, and TD-GSF-905 has been seismically qualified for a load up to 60,000 lb (30 ton), which is greater than the maximum weight of 50,000 lb for the TN-FSV cask. Safety analysis is presented in PSD 4.12, Addendum G.	14, 15	Approved
7.[c]	INRT-GSF-2	Insert Adapter ADP-GSF-3	FECF Fuel Transfer Device TD-SF-966	ADP-GSF-3 has been qualified for a load of up to 1,500 lb in each of the two adapter ports. Only one of the ports will be used for the TD-SF-966 transfer device. The transfer device contains 4 loaded CAN-GSF-131-x cans. . Safety analysis is presented in PSD 4.6, Addendum E.	16	Approved
8.	INRT-GSF-2	Lower Restraint Ring, PLT-GSF-908, and Sliding Saddles, SADL-GSF-901-X	NAC-LWT Cask for GA Fuel Payload	PLT-GSF-908 used in INRT-GSF-2 to restrain lateral movement of the NAC-LWT cask during a seismic event. Safety analysis is presented in PSD 4.12, Addendum F and PSD 4.5, Addendum S.	11, 17	Approved
9.	TD-GSF-904	TD-GSF-905 Peach Bottom Cask D-rings	Peach Bottom Cask	The support configuration of TD-GSF-904, TD-GSF-905, and the D-rings has been seismically qualified for a load up to 76,000 lb (38 tons), which is greater than the maximum weight of 70,000 lb for the fuel-loaded Peach Bottom cask.	15	Approved
10.	INRT-GSF-28	None	JMS-87Y-18.5T Cask	Safety analysis is presented in SAR-176.	18	Approved

Table 8-1. (continued).

Case #	Transfer Car Insert	Additional Load-Supporting Equipment	Fissile Material Container	Explanatory Comments	Structural Analyses References	Approval Status[b]

a. The respective equipment combinations delineated in this table, if approved, have been shown in the referenced analyses to meet requirements for Seismic Performance Category 3 (PC-3). For casks, approval also means that the equipment combination is either able to withstand the drop of a heavy object (cask lid or basket/bucket) onto the cask or transfer car insert without allowing the cask to drop from the transfer car or analysis shows this requirement is not needed

b. An approval status of not approved indicates that either seismic qualification or analysis for a heavy object drop has not yet been provided.

c. This equipment is not required for prevention of a criticality during a seismic event, and is only listed here only as operational information.

The volume of flow and the flow rate of the Big Lost River vary considerably from year to year and from season to season. During 1961, for instance, the channel was dry at the INEEL, whereas its flow rate was approximately 6.2 m^3/s (13,000 ft^3/min) in June 1965. The INTEC is located about 0.3 km (0.19 mi) from the Big Lost River, and its average elevation is about 3 m (9.8 ft) above the riverbed.

In 1986, a report was published on the results of studies on the potential flooding of INEEL facilities caused by local snowmelt combined with heavy rainfall and on flooding caused by failure of the Mackay Dam.[19]

The predicted results of four different Mackay Dam failure scenarios in the report follow:

1. Overtopping failure caused by a probable maximum flood (PMF) occurring above the dam.

2. Hydraulic (piping) failure during the 500-yr flood.

3. Hydraulic (piping) failure during the 100-yr flood.

4. Seismic failure during the 25-yr flood.

The report concludes that the most severe flooding at the INTEC would be in the event of overtopping failure of Mackay Dam caused by a probable maximum flood (PMF) above the dam. The flooding consequences were calculated using the National Weather Service computer code DAMBRK.

The report includes predicted floodwater elevations at the INTEC based on a mean ground elevation for the site. A subsequent study was performed to compute specific floodwater elevations for the INTEC and resulted in a worst-case elevation of 4,916.6 ft above mean sea level, based on INEEL data.[20]

Though the elevation of the storage area floor is 4,915 ft, the truck bay grade level is 4,918 ft. The probable maximum flood (PMF) would not result in serious flooding in the storage area or handling cave because the flood water would be present at a high level only for a limited time, a leak through the wall would have to develop, a large quantity (>5,000 gal) would have to leak to reach the canister bottoms, and the drains would have to fail to remove the water. Therefore, water entry would not seriously affect the storage area or handling cave.

Further details on past flooding history at the INEEL, flood modeling, and flooding from postulated dam failure (Mackay Reservoir) are found in Reference 19.

8.2 Effects of Decay Heat and Fuel-Water Reactions

During normal operations, ventilation air removes decay heat, and may contain fission products from the stored fuels. Exposure of graphite fuels to water could result in a chemical reaction that could generate explosive gases and could cause a release of fission products to the environment. The following discussions evaluate the risks associated with these potential effects.

8.2.1 Decay Heat

Peach Bottom, Fort St. Vrain, and ATR fuels release significant amounts of decay heat, which, if not continuously removed, could eventually have adverse effects upon both the fuel and the facility. The storage facility has a cooling system designed to remove this decay heat. The cooling system is capable of maintaining the centerline temperature of the stored graphite fuels well below the 1,100°F (866 K) upper limit. The system is also capable of maintaining the temperature of the aluminum fuels, conservatively bounded by ATR fuel, well below 482°F (523 K).

The graphite fuel centerline temperature limit of 1,100°F (866 K) was chosen on the basis of studies[21,22] and prototype INTEC tests that show that (1) insignificant quantities of fission products are released at temperatures below 1,000°F (811 K) and, (2) in essence, no oxidation occurs at a temperature of 1,400°F (1,033 K) in a closed container. The aluminum fuel maximum allowable temperature of 482°F (523 K) is low enough to prevent slumping and blistering[23] that could result in fission product release.

To ensure safe storage temperatures, the IFSF ventilation system has the capacity to provide up to 14,000 ft^3/min of air through the storage area. Based on the facility design heat load of 1.2E06 Btu/h decay heat load, this airflow is more than adequate to maintain the fuel temperatures at acceptably low levels.

A study of actual decay heat load was performed in 1990 that used actual fuel burnup in the Fort St. Vrain reactor and real cooling times. The IFSF, filled to capacity with the then-existing inventory plus projected Fort St. Vrain fuel receipts, would have produced a peak decay heat load of 767,671 Btu/h,[24] assuming all Fort St. Vrain fuel produced the maximum decay heat. The actual, or average, decay heat generation would be the maximum divided by 1.83, according to information supplied by Public Service Company of Colorado (PSC), the reactor operator and shipper.[22] Actual decay heat generation, then, would be 419,000 Btu/h.

ATR fuel produces the highest decay heating of any other fuel approved for storage in the IFSF. An ATR fuel element having a conservatively bounded irradiation history and 11 years cooling, representative of ATR fuels to be canned in the canning station, produces 12 W of decay heat.[25] A storage canister containing 16 ATR elements and six HFBR elements, which is the loading producing the highest possible decay heat generation of any canister from the canning station, would be 257 W, or 878 Btu/h. With the IFSF design heat load of 1.2E06 Btu/h, the average decay heat per position for the 636 storage positions is 1,887 Btu/h. The decay heat from fuels packaged in the canning station and from Rover UBM is well within this value.

In 1990, the IFSF storage facility cooling air exit temperature and maximum fuel centerline temperature, with a cooling airflow of 12,000 ft^3/min, were evaluated.[24] The cooling air exit temperature was calculated to be 119°F (321 K) for a filled facility containing the originally stored fuels plus projected receipts of Fort St. Vrain fuel. In addition to the facility being assumed to be full, the projected Fort St. Vrain shipments were assumed to be of the maximum heat generation for conservatism. The peak decay heat generation, assuming maximum decay heat-producing elements, of 767,671 Btu/h equates to an average of 1,207 Btu/h for each storage position. The maximum fuel centerline temperature was calculated to be 648°F (615 K). This temperature would be reached following receipt of the first newly shipped segment of Fort St. Vrain fuel, which would result in the highest per-canister heat generation.

In another evaluation, IFSF fuel and air temperatures were calculated, assuming heat transfer only through the facility walls and ceiling (involving no cooling airflow and no ground loss).[26] A maximum air temperature of 505°F (536 K) was calculated using an average total heat generation of 419,000 Btu/h. The fuel centerline temperature would reach equilibrium at 828°F (715 K), using a per-canister heat loading of 1,535 Btu/h.[26] This corresponds to the maximum possible heat generation of the hottest canister at the time that the facility would be filled. In the evaluation, a conservative rate of temperature rise, assuming adiabatic conditions, for the facility was also evaluated. The facility temperature rise rate was calculated to be 0.344°F/h.[26] The time duration required for the facility temperature to rise from an initial temperature of 100°F (311 K) to 400°F (477 K) would be 870 hours, or 36 days.

All the assumptions used in these calculations are considered to be very conservative. The values assumed for Fort St. Vrain fuels envelop all other fuels stored in the facility, including those processed in the fuel canning station.

In an analysis of decay heating of long-term-cooled ATR fuel elements, thermal heating of the elements was conservatively assumed to produce 15 W per element.[27] Assuming the 15 W per element value and a canister containing 18 ATR elements, the canister contents would generate 270 W (921 Btu/h). The actual maximum heat generation of a single canister would be for one containing 16 ATR and six HFBR elements, producing 257 W (878 Btu/h). The effects on the facility and the cooling air temperature calculations for Fort St. Vrain fuel, at 1,207 Btu/h per canister, envelop the effects and calculations for fuels processed in the canning station and for Rover UBM.

An evaluation performed during 1995 showed that 921 Btu/h canning station canisters would rise to a temperature of approximately 381°F (467 K) in 144 hours, or 6 days, in the insulated canning station with no external heating.[27] In ambient still air, the same canister would reach a maximum temperature of 268°F (404 K). In the normal storage condition, with 12,000-ft^3/min cooling airflow, the temperature of the fuel would remain significantly lower. Because the canning station is insulated and designed to retain heat, the 381°F (467 K) calculated temperature is conservative in the free ambient air environment of the storage area or the fuel handling cave in the abnormal condition of no cooling airflow. An additional conservatism is the significantly lower actual heat generation per canister compared to the assumed value.

The substantial margins between calculated and acceptable facility and fuel temperatures will permit sufficient time to recover from an accidental shutdown of the ventilation system. At least 36 days without cooling airflow would be required before a facility temperature of 400°F (477 K), would be approached, at which point long-term hazardous effects on the facility could result (see Subsection 8.6.2.3). Also, it would take 22 days before aluminum fuel temperatures could reach levels that would be detrimental to the fuel or the storage canisters (see Subsection 8.6.2.2). Because the shortest time necessary to overheat is for aluminum fuels, that 22-day duration is the basis for controls to prevent overheating. The IFSF ventilation system provides sufficient cooling to the stored fuels, with adequate allowance for the abnormal conditions of reduced or loss of coolant airflow.

8.2.2 Fission-Product Release

Significant fission-product and heavy-element inventories exist in irradiated Fort St. Vrain and Peach Bottom fuel elements. The fission-product inventories are based on 6-yr of reactor operation at 837 MW for Fort St. Vrain fuel and 2.5 yr of reactor operation at 114 MW for Peach Bottom fuel.[28] Because Fort St. Vrain reactor operations were halted sooner than expected, the burnup was lower than the assumed values used for calculations. Cooling times are more than 6 yr for Fort St. Vrain fuel, and more than 20 yr for Peach Bottom fuel. Therefore, all radiation exposure calculations for these fuels are conservative. Fission product inventories of fuels processed in the canning station, except ARMF and CFRMF fuels, are contained in the radionuclide inventory of CPP-603 fuel.[25] Fission product inventories of ARMF and CFRMF fuels, as shown in the radionuclide inventory of ARMF and CFRMF fuels, are much lower than ATR fuels.[29]

Fission-product release can occur from fuel-water reactions, loss of cooling, mechanical damage, or an accidental criticality. However, during normal operations, the physical characteristics of the fuel, in addition to the controlled environmental conditions in the storage area, preclude fission product release from the fuel.

Fission products from Fort St. Vrain, Peach Bottom, and Rover fuels are contained within the fertile and fissile particles, both of which are coated with graphite (see Figure 8-1), which serves as the primary barrier for retaining the fission products. (This is not the case for Rover UBM, since the graphite coating has been burned off.) In addition to the graphite coating, the Fort St. Vrain particles are coated with a layer of silicon carbide and then a second layer of graphite to improve further the fission-product retention characteristics of the fuel. Fuels processed in the Fuel Canning Station have cladding that, though possibly partially defective, serves as a partial barrier for retaining the fission products, and the fuel meat itself also retains most fission products. The canister containing the fuels serves as a secondary barrier. Once the fuels are canned and dried, there is no significant driver to release fission products. However, the facility ventilation system filters serve as the final barrier.

One Rover UBM can contains a Rover fuel piece (approximately 1 in. diameter and 6 in. long) that was not charged to the burner system.

Tests on the coated particles showed that both the Peach Bottom and Fort St. Vrain coatings adequately retain fission products under the high-temperature operating conditions of the reactor and under storage conditions.[21,22] The tests also showed that fission products can be driven from the fuel particles, but only in insignificant quantities at temperatures at least 1,000°F (811 K) but less than 3,000°F (1,922 K).[30] Additional experiments with graphite fuels showed that the release of fission products from the coated particles is not rapid until a temperature near the melting point of uranium-thorium carbide (4,450°F) (2,727 K) is reached.[31] Because, under normal storage conditions, the centerline temperature of the hottest stored fuel elements will remain below 648°F (615 K), no release of fission products is expected. In any event, were a fission product release to occur, the HEPA-filter system would remove a minimum of 99.9% of the radioactive particulate prior to exhausting the release to the atmosphere.

In the case of the Rover UBM, the original fuel coating is largely or completely absent due to partial processing through the burners. However, the Rover UBM arrives at the IFSF already contained in closed SS cans. The can lid is closed using a grafoil gasket torqued to the lid by turning its closing mechanism. The cans are shown to be leak resistant and to retain their integrity in a drop of 24.3 ft, the maximum credible drop in the IFSF.[32,33] Initial testing indicates that the torqued grafoil gasket on the Rover UBM can does not leak, but this document considers the gasket only leak resistant. The can body with its welded bottom is constructed to be leak-tight.[34] If for any reason a Rover UBM can is opened after the lid has been torqued shut, the grafoil gasket must be replaced prior to the lid being reinstalled. The fission product release from a possible criticality accident involving Rover UBM is discussed in detail in Section 8.6.1.5.3.

8.2.3 Fuel-Water Reaction

As mentioned in Section 1, dry storage is the preferred storage method for the HTGR fuels because of the possibility of water-carbide reactions. The probability of occurrence of these reactions is very low because the facility is designed for and maintained to provide dry storage conditions, because the fuel is stored in canisters, and because of the effective isolation of the metallic carbides from exposure by the fuel matrix itself. The carbon-steel (CAN-GSF-101) canisters and the original canning station (448646 on flange) canisters could admit water only from the top, and then only water from a roof leak directly or

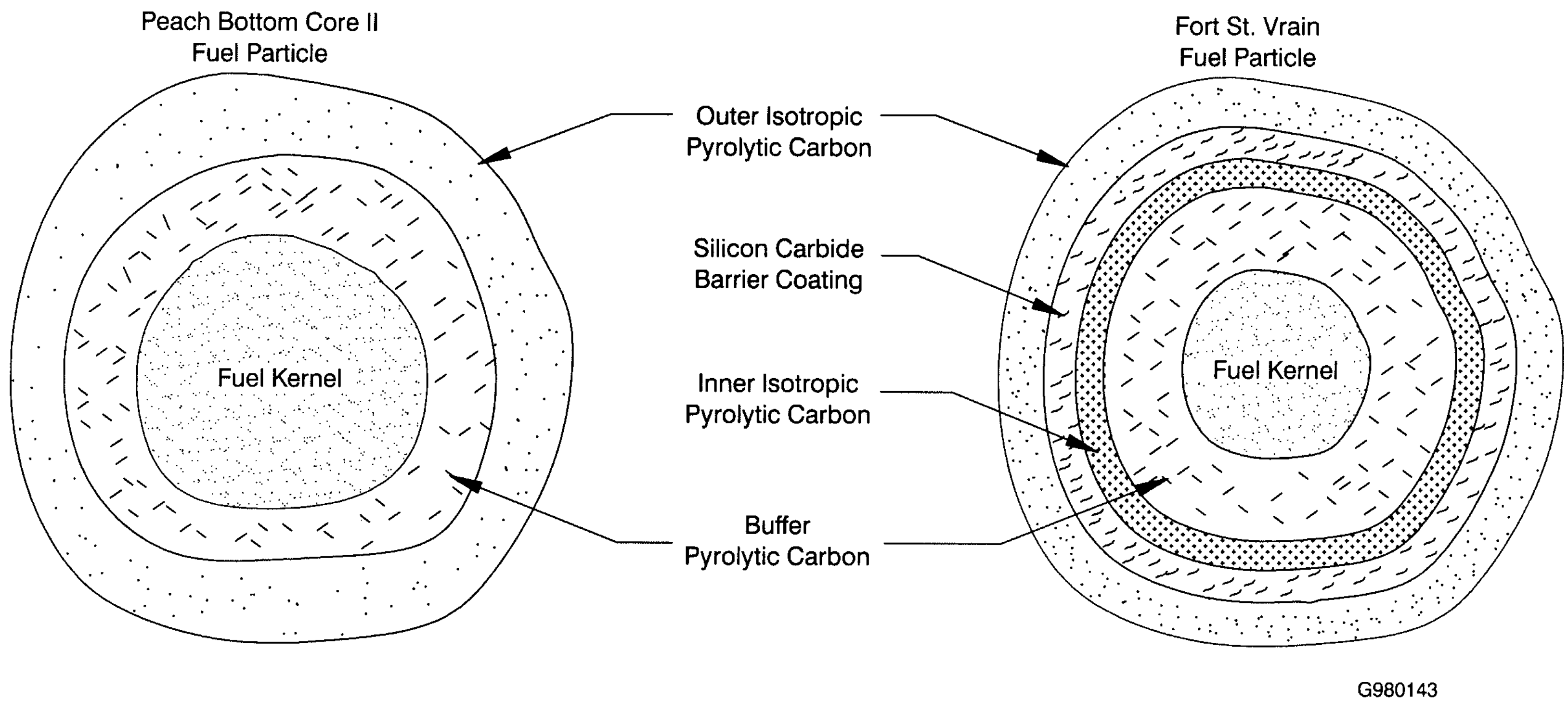

Figure 8-1. Coated fuel particles.

nearly directly over the canister. No credible condition exists in which the facility could be flooded to the top of the canisters, as described in Subsection 8.1.2. Even if water did enter, the fuel graphite matrix and the coatings (three for Fort St. Vrain fuel and one or two for Peach Bottom fuel) on the particles (pyrolytic carbon and silicon carbide coatings) would very effectively isolate the metallic carbides from contact with the water.

The Rover UBM canister (CAN-GSF-276) lids are designed specifically to shed any water that should leak onto or splash near the canister. The Rover UBM canister bottom is leak tight. Rover UBM, although lacking a coating, is enclosed in leak-resistant SS cans inside the canister with its water-shedding lid. These Rover UBM cans also have leak-tight bottoms and water-shedding lids. Thus, the Rover UBM also has two barriers between it and any water that may enter the fuel storage area.

Peach Bottom fuel was packaged underwater at the Peach Bottom reactor, then dewatered before shipment to the INTEC. The possibility was recognized that some residual water, or even water-filled cans could be brought into the IFSF. Shipper quality control and INTEC receipt inspection, including cask atmospheric sampling, were relied upon to detect whether any water remained in the Peach Bottom cans before bringing them into the IFSF. Once inside the IFSF, the cans were cut open and the top ends of the fuel elements were cut off to allow storage in the shorter IFSF canisters. No water was detected during this activity. No more Peach Bottom fuel is to be shipped to the INTEC. Therefore, there is no further risk of water introduction from Peach Bottom fuel receipts, and there is no indication that water ever was introduced by this means.

Once the fuel is in the handling cave or storage area, there is low probability that water will contact the fuel, as discussed in Subsection 8.6.1. Administrative and physical controls preclude the inadvertent addition of water into either area. Both areas have fire-fighting designations that allow no water.

Fuels processed in the Fuel Canning Station were previously stored underwater. Drying in the canning station precludes introduction of water into the storage area. Water can be retained in a fuel container after removal from water storage and transferred into the IFSF fuel handling cave. Any spilled water observed on the facility floor or in the drip pans that are provided must be removed before the transfer of any additional fuel into the handling cave. Fuels brought in from CPP-749 will be evaluated on a case-by-case basis for water content before being brought in to the IFSF.

WAPD fuel contains sodium-potassium (NaK) between fuel pellet cladding sheaths. An explosive reaction could occur if NaK were exposed to uncontrolled amounts of air or water. This is considered an unlikely event. If the cladding failed during heating in the canning station, the limited oxygen in the canister and the large thermal mass of the buckets and canister would prevent significant overheating. If the cladding failed due to heating in storage (as a result of an extended cooling outage), the canister lid would limit air exchange and the thermal masses of the canister and bucket would limit overheating. The WAPD fuel was inspected by video camera on May 19-20, 1997, and there is no visible evidence of pitting, corrosion, or rupture of the cladding. If the stainless-steel cladding has been penetrated, the possible NaK-water reaction has already occurred harmlessly underwater. On some of the WAPD fuel, there is evidence of white corrosion scale.[35]

The WAPD fuel, when in storage, will have been dried in the Fuel Canning Station; therefore, no water is expected to be available within the fuel storage configuration. In the unlikely event that water from an external source were to enter the canister containing WAPD fuel, a NaK-water reaction is still not likely to occur because the NaK is still within the stainless-steel cladding, which if intact, will continue to provide a barrier between the water and the NaK. It is unlikely that the stainless-steel cladding will be damaged after drying, and no water will be present after drying.

BMI-Spec fuel consists of three fuel plates. The fuel matrix is an uranium-molybdenum alloy and is plated with nickel. The fuel plates are clad in aluminum, and were originally stored in an open-top aluminum can, all of which was overpacked into an open top stainless-steel can in August 1996. Before shipment to INTEC, approximately ¼-in.-diameter holes were punched through the cladding and fuel meat in two places on each plate to obtain post-irradiation samples. Since the holes exposed fuel material, a small area of uranium-molybdenum was initially subjected to water corrosion.

Formation of metal hydrides and a possible pyrophoric reaction due to water corrosion of the BMI-Spec fuel is discussed in Addendum B to this SAR. The CFRMF core filter also has the potential of a pyrophoric reaction. This potential is evaluated in Addendum B - Supplement to this SAR.[36] In summary, consequences of a possible pyrophoric reaction involving the CFRMF core filter would be comparable to those discussed for BMI-Spec fuel and are well within evaluation guidelines.

Canisters being processed in the Fuel Canning Station may contain significant amounts of water prior to drying. If an event occurs during a canning station operation that requires personnel entry when such a canister is in the canning station, it might be necessary to remove the canister from the canning station, place it into the shuttle bin, and move the shuttle bin into the storage area to provide shielding. Other fuels, like the TRIGA, WAPD, and BMI-Spec fuels from the CPP-603 South Basin, may require a different recovery sequence, as discussed in PSD 4.12 Addendum B or its fuel-specific supplements. An administrative control prohibiting removal of the canister from the shuttle bin prior to complete drying while on the storage area side of the shield wall prevents the potential intrusion of water from such a canister into the fuel storage array.

Physical controls minimizing water intrusion into the fuel handling or storage areas include (1) the absence of water sources or pipes within these areas, (2) thick concrete walls, and (3) a thick concrete roof with membrane roofing.

The roof is made up of 3 ft of concrete, covered by a built-up membrane roofing. The built-up roofing is covered up around all equipment pads and up the parapet, which surrounds the roof of the facility. The roof is sloped to the north and south from the center and five drainlines remove water from the edges. Some roof overhang from the north-south and east-west truck bays drains onto the IFSF roof. This water is likewise conveyed away by the drains. Any possible water leak through this roof is likely to be small (drips rather than streams) because of the roof design. The canisters containing graphite fuels, while not designed to be watertight or airtight, have lids that would exclude most of the water that might fall on the lid.

Water ingress through the light replacement access doors on the north side of the facility is unlikely because the doors are equipped with neoprene rubber gaskets to provide a seal.

8.3 Radiation

At the IFSF, highly irradiated fuels can present a significant radiation hazard to operating personnel; however, protection against this hazard is provided through the use of shielding, instrumentation, and administrative procedures.

Shielding walls and windows, and shielded casks protect personnel during fuel transport, handling, and storage. Neither are shipping casks opened or is irradiated fuel handled outside the storage facility. Rather, all irradiated fuel handling operations are performed in the fuel handling cave and in the fuel storage area using remote methods. Some handling of unirradiated fuels is done outside the handling cave. As discussed in Subsection 8.6.3, casks used for transferring irradiated fuels into or out of the IFSF are evaluated for drops and have been shown to retain their lids following accidental drops from equal or greater heights than could occur in the IFSF. Lid bolts are not removed from the casks until the casks are mounted on the transfer car, after which a drop is not possible.

Shielding is provided in the facility so that the calculated radiation fields at grade levels external to the storage facility and accessible to personnel do not exceed 1.0 mrem/h. These calculated values do not meet the full-time occupancy design dose rate (0.1 mrem/h) requirement of the 10 CFR 835 regulations.[37] However, radiation measurements taken after various fuel receipts indicated that the radiation fields from the storage facility were lower than 1.0 mrem/h.[38,39] During operations, access is controlled according to the requirements of the INEEL Radiological Control Manual.

In the case of Rover UBM, drum and can handling take place in the cask receiving area. Although Rover UBM cans are contact-handleable, exposure from repeated handling is minimized by using a reach tool to increase personnel distance from cans. In addition, all nonremote operations are carried out in accordance with the requirements of the INEEL Radiological Control Manual.

When fuel is present, a relatively high radiation level exists inside the facility (except in the control and instrument rooms). To control access to the facility and prevent accidental exposure of personnel, only two doors permit access to potential radiation areas, one to the crane maintenance area and the other to the shielding door enclosure. Both doors normally are locked, and access is possible only with proper authorization. Before personnel access to the handling cave is permitted, all fuel must be removed from the fuel handling cave if such removal is required to reduce radiation to acceptable levels. In addition, the movable shielding door will be closed, if necessary, to minimize radiation levels in the crane maintenance and fuel handling cave areas.

The transfer car is designed to provide shielding to personnel located in the receiving area, the PCS, and the transfer car pit. If the transfer car is in the handling cave, either a cask or the blind adapter plate must be in place to prevent radiation shine through the opening provided for mounting a cask. The transfer car pit is posted as a high radiation area and a contamination area, and is also an enclosed area. Entry into the transfer car pit requires a radiation work permit, which ensures that radiation levels are known and that sufficient controls are in place to ensure worker safety. The transfer car may not be moved while personnel are present in the transfer car pit.

An external ladder provides access to the roof. This ladder is located on the north side of the IFSF and access to the ladder is kept locked. Supervisory approval and procurement of a radiation work permit are required for personnel to access the roof via the ladder. Also, the ladder is posted with a warning sign stating that radiological control personnel must be contacted prior to use of the ladder.

Doors are provided on the north wall of the storage area for access to the light fixtures. These doors are filled with 6 in. of lead shot for shielding. The doors are approximately 20 ft above grade and are accessible only by means of a scaffold, ladder, or man lift. Therefore, any radiation exposure hazard is easily controlled by normal radiological control practices.

Administrative controls, appropriate work permits, and radiation instruments also are used to protect personnel from high-radiation exposure.

8.4 Fire

The possibility of an IFSF fire is extremely low. The facility is constructed entirely of concrete and steel and has thick concrete shielding walls installed between functional areas. Thus, the facility structure will not support combustion, and combustible materials[e] (other than the cardboard tubes for the Rover fuel) will not be stored in the facility. However, should a fire occur (for example, in electrical or control cables), the internal shielding walls will contain it within the local area of the initial combustion. Because interaction among areas is highly improbable, the fire potential of each area and of the graphite fuels is discussed separately. A study of fire protection and the life safety code in the IFSF was performed by an outside consulting firm. No significant deficiencies were found.[40]

Based on the limited fire potential for graphite and the fuel storage methods, a fire in the fuel storage area is considered extremely unlikely. Therefore, a fire suppression system is not provided in the storage area to address a fuel fire. The only possible fire hazard associated with the stored fuel is with the Rover fuel cardboard tubes in the event of a postulated complete loss of cooling air flow. Even in this case, analysis results indicate that sufficient time would be available in which to take corrective action (see Subsection 8.6.2).

8.4.1 Graphite Fuel Oxidation

Oxidation of graphite begins at elevated temperatures (1,100°F [866 K] in free air and 1,400°F [1,033 K] in a closed container) and varies directly with the temperature. Tests performed by the U.S. Bureau of Mines on 10 graphite dust samples dispersed in air indicate that none of the samples would ignite in a high-temperature furnace below 1,546°F (1,114 K). In addition, regardless of particle size, concentration, and temperature, the graphite sample could not be made to explode. In closed containers, graphite will not, in essence, oxidize at 1,400°F (1,033 K).[22] Because the powder form of graphite provides more surface area for the reaction, these tests envelop the high density graphite contained in fuel stored at the IFSF. Thus, graphite is a relatively inert material, and 1,100°F (866 K) is a reasonably conservative upper limit for the centerline temperature of the stored fuel.

The method of storing the spent fuel in closed, spaced canisters serves to prevent fuel overheating and any interaction between canisters. The canister lids isolate each canister and restrict air exchange around the fuel. The steel canisters will rapidly transmit the decay heat to the cooling air. The storage racks space the canisters for effective and efficient heat transfer. The racks enclose the canisters for positive cooling, and the cooling system has a double system of automatic-start backup blowers. The cooling airflow limits potential graphite oxidation by keeping fuel temperatures within acceptable limits. With these design precautions, an oxidation reaction of the fuel would require the conditions of failure of the entire cooling system for an extended period of time, failure to take remedial action to restore airflow, and failure of the storage canisters.

8.4.2 Facility Fire-Control Systems

The INTEC fire-water system serves the CPP-603 FSB, the cask receiving area, and the fuel storage facility. However, because of the potential fuel-water reaction and the sensitivity of Rover fuel to water, pipes carrying water are not present in the fuel handling cave or the fuel storage area, and water will not be allowed in these areas when graphite fuel is present.

A 125-lb dry fire extinguisher, mounted on wheels, with a 50-ft hose is available in the CPP-603 truck bay (south) for fighting fires in the IFSF.

---

e. Graphite is noncombustible and is discussed in detail in Subsection 8.4.1.

8.4.2.1 *Fuel Handling Cave.* Electrical fires could occur in the fuel handling cave. Though the possibility is unlikely, an electrical fire could start a graphite oxidation reaction (a rather slow oxidation with no flames) in this area. The graphite material is, in general, contained in metal containers. Two fuels, Rover fuel and Fort St. Vrain, may be moved between containers, and at those times would not be contained in metal cans. There is no electrical wiring near the material unless the wiring is isolated within conduit or by metal containment, such as in the Fuel Canning Station. Fire extinguishers are located near the door to the crane maintenance area and, if the need arises and if radiation fields permit, personnel entry can be used directly in both the crane maintenance area and the fuel handling cave. If entry were not possible, the limited amount of combustible material and the lack of sufficient energy to sustain graphite combustion would soon extinguish any credible fire. The dry-chemical fire extinguishers contain a small but insignificant amount of hydrogen, so the agent does not have to be counted as moderator material.

8.4.2.2 *Fuel Storage Area.* The irradiated graphite fuel elements are stored in the fuel storage area of the IFSF in 1/4-in.-thick steel canisters having lids. The canisters, in turn, are placed in carbon-steel racks that position the canisters on nominal 24-in. centers in a staggered arrangement.

The fire potential associated with this area of the facility is considered low because of (1) the construction of the facility, (2) the method of storing the fuel, (3) the characteristics of graphite fuel, and (4) the prohibition of storage or use of combustible materials in the storage area when fuel is present, other than the cardboard tubes containing the Rover fuel. Tests run at the INTEC showed that individual cardboard tubes will not support combustion. Additionally, the cardboard tubes are within the canisters, which restrict air exchange. Therefore, other than the cooling system, no fire prevention or fire-fighting equipment is located in this area. The high temperatures that could be generated by decay heat from the Fort St. Vrain, ATR, or Peach Bottom fuels are self-generated, and the Rover fuel cardboard tubes will not experience these high temperatures.

8.4.2.3 *Crane Maintenance Area.* The crane maintenance area is a limited access area; that is, personnel access is permitted for specified periods of time under certain conditions. Thus, should a fire occur in the crane maintenance area, personnel could combat it directly using portable fire extinguishers provided for the crane maintenance area. Very little combustible material is in the area, so any fire would be small and of short duration.

8.4.2.4 *Cask Receiving Area.* When fuel is present in the cask receiving area, the fuel is usually contained in a sealed fuel shipping cask, and a fuel-water reaction or water-induced criticality is not possible. If unirradiated fuel is being handled outside the handling cave, administratively controlled mass limits are enforced. Hose connection stations supplied by the INTEC fire water system provide protection for the cask receiving area. In addition to hose connection stations, suitable portable fire extinguishers are also available for use on fires where water is not a suitable extinguishing agent.

8.4.2.5 *Control Room and Generator Room.* The primary fire potential in the facility control room is in the instrumentation, electrical, and control wiring. Because fuel is not stored in this area, fire protection is provided by several portable extinguishers suitable for use on electrical fires. Portable fire extinguishers are also provided for the generator room.

8.4.2.6 *Standby Generator.* A propane-fueled generator has been used at the IFSF to provide standby electrical power. This generator is located in a separate, reinforced concrete room. Safety precautions and design features have been provided to minimize hazards associated with the propane and the propane storage tank, located outdoors about 25 ft from the generator and the storage facility. This generator is being replaced by the INTEC standby electrical power bus. At the completion of SO testing of the new system, scheduled for late fiscal year 1996, the propane system will no longer be used.

8.4.2.7 Exhaust Blower Plenums. A fire could begin in the exhaust blower plenums only if some combustible materials were present, which is unlikely.

8.4.2.8 Switchgear. It is possible for a fire to begin in the switchgear of the normal or standby power system. The switchgear is located on the motor control panel. A fire beginning in this area could be put out with a portable CO_2 extinguisher or with an ABC fire extinguisher. Such a fire could disable the blowers until repairs were made.

8.5 Postulated Abnormal Occurrences

A summary of significant postulated abnormal occurrences appears in Table 8-2. Additional abnormal occurrences are discussed in the following subsections.

8.5.1 Flooding of the Handling Cave or Storage Area

Massive failure of the CPP-603 basin parapet could result in water entering the transfer pit. It has been shown that for the DBE, the basin walls may leak but will not fail and cause flooding of the IFSF into the fuel handling cave and the fuel storage area.[41,42,43] The floor of the IFSF cask receiving area is above the maximum probable flood level.

The storage area floor is a floating design, with an expansion joint between the storage floor edges and the wall. The expansion joint was caulked. The expansion joint could provide a leak path for water if for some unlikely reason, the ground below the IFSF became saturated and if sufficient hydrostatic head developed. However, the facility footing is immediately below the floor and, if ground saturation occurred, the saturation plume would have to move horizontally under the footing, then upward and around the edge of the floor to get into the storage area. The same potential inleakage path would also serve as a water removal path. This, coupled with the storage area drains, makes it very unlikely that a significant amount of water could accumulate in the storage area.

Retesting of the drainlines has not been done. Video inspection of some areas under the racks has been done and has shown no evidence of water intrusion other than possibly very slight condensation.

8.5.2 Loss of Normal Electrical Power

The loss of normal electrical power to the storage facility is not a serious condition and, other than inconvenience, has no effect upon the facility's integrity or ability to contain the fuel and fission products safely. Upon a loss of normal power, the INTEC standby power system automatically provides power to equipment connected to the standby power bus, which automatically switches certain equipment (cranes, standby lighting, blowers, sump pump, transfer car, fire alarms, evacuation alarms, security alarm system, canning station Distributed Control System (DCS), facility Criticality Alarm Systems (CAS), shield door, remote area monitors (RAMs), and egress emergency lighting) to a standby power generator within about five minutes after loss of normal power. In the unlikely event that the automated control of standby power system is temporarily out of service when normal power is lost, the CAS, the building egress emergency lighting, building RAMs, and the DCS for the canning station have approximately 2-hr battery backups. Furthermore up to ten days without cooling air supply has no significant effect on the stored fuel temperature. Ten days is sufficient time to restore cooling air flow, even in the extremely unlikely event that a portable generator has to be provided for this purpose. (See Section 8.6.2 for a detailed discussion of cooling air flow.) Thus, loss of normal power does not endanger the facility, the environment, and personnel.

Table 8-2. Postulated abnormal occurrences for the IFSF.

Postulated Abnormal Occurrence	Possible Causes	Possible Effect	Prevention, Control, or Mitigation: Design	Administrative	Detection
1. Fire or explosion during opening of cask in fuel handling cave.	Fuel-water reaction in cask containing water and broken carbide-fuel element generates combustible gases.	Airborne radioactivity in handling cave; radioactivity buildup on high-efficiency particulate air (HEPA) filters.		Casks are loaded dry at shipper's facility.	Visual
2. Electrical fire in control room from short in electrical system.	Failure of wiring insulation from power overload.	Cessation of operations because of equipment damages.	Equipment designed to electrical code.	Operation within design parameters.	Visual
3. Radiation exposure in fuel handling cave.	Operator enters high radiation area.	Radiation exposure received in excess of dose limits.	Locked access door with alarm.	Operator training.	Personnel dosimetry
4. Canister containing fuel is dropped.	Improper crane operation or equipment failure.	Release of fission products to the facility.	Equipment design, positive locking closure on crane hook. Facility and ventilation filters will contain fission products.	Operator training.	Visual
5. Fuel is spilled from canister.	Equipment failure, canister is dropped, lid comes off.	Difficult recovery.	Equipment design.	Preventive maintenance, operator training.	Visual
6. Fuel is suspended from crane, trolley motion fails.	Trolley motor fails, no backup.	Difficult recovery.		Preventive maintenance, operator may be able to detect problem before event occurs.	Visual

Table 8-2. (continued).

Postulated Abnormal Occurrence	Possible Causes	Possible Effect	Prevention, Control, or Mitigation: Design	Administrative	Detection
7. Exhaust HEPA-filter failure.	Overpressure or fire.	Minor contamination of local area.	Filter differential pressure (DP) instrumentation; low combustible material content in facility.	Filters changed out on high DP or radiation level.	Filter DP and radiation instrumentation
8. Short-term loss of coolant flow.	Loss of power or air intake freeze-up.	Fuel temperature increase; minor contamination in facility.	Standby power; backup systems.	Preventive maintenance; switch blower and remove ice.	Alarm
9. Water is spilled from canning station canister.	Canister is removed from canning station before drying to allow personnel entry; canister is then dropped.	Water-carbide reaction.	Lifting equipment design; lids on storage canisters; graphite matrix surrounds carbide-coated particles.	Removal from shuttle bin prohibited.	Visual
10. Fire or explosion caused by propane leak.	Propane line fails, propane ignites.	Loss of availability of standby power (until new system on line), damage to generator and generator room.	Propane line is doubly contained.	Solenoid supplies propane only during generator operation (line not always pressurized).	Visual
11. Shielding window or crane gearbox leaks oil.	Leaking gasket or seal.	Oil drips from crane or seeps down wall below window.	Seals provided; physical impact with window unlikely.	Crane is not parked in storage area to minimize radiation exposure.	Visual
12. Electrical fire in crane cables.	Crane severs cable in crane cable tray.	Loss of crane power redundancy.	Limit switch prevents sufficient crane overtravel to server line (touching cable tray possible); circuit breaker will shut off power upon short circuit.	Operator training.	Loss of crane power will disable crane until backup system is activated.

Table 8-2. (continued).

Postulated Abnormal Occurrence	Possible Causes	Possible Effect	Prevention, Control, or Mitigation		
			Design	Administrative	Detection
13. Blowers pressurize the facility.	Supply blower operates without a corresponding exhaust blower.	Possible spread of contamination.	Control system is designed with interlocks to require exhaust blower to be in operation before the supply blower.	In manual operation, procedure requires exhaust blower on alone or before supply blower.	CAMs detect airborne contamination.
14. Rover UBM can is dropped in PCS through to transfer car pit.	Transfer car and/or insert not in position.	Difficult recovery.	Insert for Rover UBM buckets is designed so that Rover UBM cans cannot fall through to pit.	Procedure requires transfer car, insert/adapter and buckets to be in position in PCS before Rover UBM can is brought into PCS.	Visual
15. Worker exposure handling contact handleable fuel/fissile material (e.g., Rover UBM or Rover fuel) in cask transfer area/PCS or cave.	Fuel/fissile material causes higher field than expected.	Radiation exposure received in excess of dose limits.	Handling tool designed to increase worker distance from UBM.	Operator training; dosimetry; RWP/radcon requirements.	Dosimetry
16. Rover UBM can is dropped during transfer to the PCS.	Improper rigging, equipment failure.	Operational delay.	Equipment design; hoisting/rigging.	Adherence to hoisting/rigging handbook requirements; operator training.	Visual
17. Rover UBM bucket dropped in cave (including into shuttle bin).	Equipment failure.	Difficult recovery.	Equipment design: positive latch tool.	Adherence to hoisting/rigging handbook requirements; operator training.	Visual

Table 8-2. (continued).

Postulated Abnormal Occurrence	Possible Causes	Possible Effect	Prevention, Control, or Mitigation: Design	Prevention, Control, or Mitigation: Administrative	Detection
18. Rover fuel tube is dropped into transfer car pit.	One or more of the following is not in the correct position: • Transfer car • Rover UBM insert adapter • Cover plate(s) or Rover fuel transfer device(s).	Difficult recovery.	For Rover fuel tubes, special Rover fuel transfer devices or cover plates are used in the insert adapter ports to prevent tubes falling through, without disabling port drainability.	Procedure requires transfer car, insert/adapter and cover plate(s) or Rover fuel tube transfer device(s) to be in place before Rover fuel is placed in the transfer car.	Visual
19. Rover fuel tube is dropped during transfer, but not into transfer car pit.	Equipment failure; operator error.	Operational delay	Equipment design.	Operator training.	Visual
20. One or more 6M drums filled with Rover fuel tubes (≤600 g U-235 per tube) become flooded in cask receiving area.	Water (e.g., wet/melting snow/slush) is on the portion of the roof which fails directly over open drum(s); OR Fire or other water enters via hose.	Operation delay.	Design of drums used (with 2R inner containers) prevents Rover fuel criticality even if multiple, contiguous, filled drums are flooded.	A maximum of one fuel-containing drum may be open at a time. OR Fire and other water is prohibited from the CAS coverage zone during Rover fuel handling.	Visual

Table 8-2. (continued).

Postulated Abnormal Occurrence	Possible Causes	Possible Effect	Prevention, Control, or Mitigation: Design	Prevention, Control, or Mitigation: Administrative	Detection
21. Rover fuel tube(s) dropped onto, between, or into 6M drums filled with Rover fuel tubes (≤600 g U-235 per tube) in cask receiving area. Open drums may be dry or flooded (See PAO 20, above.)	Equipment failure; operator error.	Operational delay	Design of drums used (with 2R inner containers) prevents Rover fuel criticality even if multiple, contiguous, filled drums are flooded.	Operator training; A maximum of one fuel-containing drum may be open at a time.	Visual
22. Fuel-filled transfer device in Rover UBM insert adapter becomes flooded in the PCS.	Water (e.g., wet/melting snow/slush) is on the portion of the roof which fails directly over fuel; OR Fire or other enters via hose.	Operational delay.	Design of transfer device prevents Rover fuel criticality even if flooded.	None for water from failed roof; Fire and other water is prohibited from the CAS coverage zone during Rover fuel handling.	Visual
23. Fuel-loaded cask falls from transfer car into cask transfer car pit.	Improper crane operation or equipment failure causes heavy object to fall on cask.	Direct radiation exposure or release of fission products to the facility.	Crane and rigging equipment design. Fuel handling cave ventilation system and filters will contain fission products.	Operator training.	Visual

Table 8-2. (continued).

Postulated Abnormal Occurrence	Possible Causes	Possible Effect	Prevention, Control, or Mitigation		Detection
			Design	Administrative	
24. Fuel-loaded cask falls from transfer car into cask transfer car pit.	Improper crane operation or equipment failure causes heavy object to fall on cask.	Potential criticality.	Crane and rigging equipment design. Transfer car pit sump and pump. Transfer car and insert design. Criticality Alarm System.	Operator training. Moderator controls in IFSF.	Visual

Note: Concerns about potential pyrophoric reactions of fuels processed in the Fuel Canning Station are addressed in Addendum B to this safety analysis report.

8.5.3 Mechanical Failure

All operating equipment is subject to mechanical failure. However, in designing the IFSF, extensive efforts were made to provide a backup for those systems that could, affect, in any way, the safety of the facility if they failed. For example, spares are provided for ventilation equipment to cause, should the operating unit fail, the standby unit to start automatically. In the case of instruments, particularly those indicating radiation levels, sufficient spares are available to prevent the loss of one unit from seriously impairing the operator's knowledge of facility conditions. In cases where spare units are not available, the equipment is designed for quick and easy removal either directly or remotely from the facility to a low radiation area for maintenance. In some cases, where the item cannot be removed (for example, the cask transfer car), all movable parts are located in an accessible low-radiation area. Therefore, through a combination of standby systems and equipment and remotely removable equipment, a mechanical failure does not represent a hazard to personnel, the facility, or the environment.

Though unlikely, a mechanical failure or an operator error could cause the dropping of a storage canister on top of the storage rack. If a canister were dropped onto the storage rack, some rack damage could occur. If the canister lid were to come off, some fuel could spill out. This could create a difficult recovery situation and could cause fuel damage that might contaminate equipment. Facility features would prevent a major contamination spread or release. A criticality would not occur (see Subsections 8.6.1.4.10 through 8.6.1.4.13).

The crane grip switch is protected to prevent inadvertent release of a canister. The crane has limit switches that prevent suspending a canister directly over the open area beside the storage rack. A canister could still fall into this area after being dropped. Several recovery methods could be used; however, the recovery would not be a routine operation. Therefore, no specific equipment has been designed or built for this purpose. Prior to performing this type of recovery operation, special procedures would be prepared and approved by INTEC management.

Another postulated abnormal occurrence scenario is one in which the rigging of the crane fails. The presence of anyone beneath the crane at the time of failure is extremely unlikely. Because the failures would take place within the shielded area, the possibility of radiation exposure to any personnel in the area is remote.

The following abnormal occurrence actually happened. In October of 1983, the 2-ton capacity hoist located on the bridge-mounted PaR manipulator was being used to retrieve the 10-ton crane (which was inoperable) from the storage area. The shielding-wall plug located on the upper wall dividing the fuel storage cave from the fuel handling cave, as configured at that time, had to be lowered for the retrieval of the 10-ton crane. The shielding plug pivoted on hinges located on the bottom of the plug. When lowered, the plug pivoted down 110 degrees into the fuel storage area. The 2-ton capacity hoist was attached to the shielding plug and the plug was lowered to the down position. When operations personnel tried to disengage the hoist jaws from the shielding plug, the jaws would not open. They then attempted to raise the shielding plug to the closed and secured position to try to disengage the crane jaws. The 2-ton capacity hoist jaws failed and the shielding plug fell to the open position. The force of the fall broke the hinges that attach the plug to the wall. The shielding plug then fell approximately 8 ft to the top of the fuel storage rack located in the fuel storage area.

Management and criticality safety personnel were notified. Visual inspection, through the viewing window, of the area where the shielding plug landed showed no significant damage except for bent lifting ears on several fuel storage canisters and minor deformation of the rack surface. A camera survey of the area south of where the shielding plug landed showed no damage. After appropriate analysis of the situation, corrective action was taken. The damaged part on the 2-ton hoist was replaced, the hoist was load-tested and returned to service. The shielding plug was removed from the storage area and the damaged storage canisters were inspected and repaired. The shielding plug has been redesigned to be lifted out in sections rather than to pivot downward.

Damage to the canisters or storage rack caused by a dropped canister would not be expected to be greater than that sustained by the drop of the shield plug onto several canisters. An analysis has shown that there is insufficient spacing between the stored canisters in the storage area for a dropped canister, if it impacted on its end or side, to penetrate the rack top surface and break into the space between canisters.[44] The analysis also shows that a canister that impacted on a corner of its end could not penetrate and would not cause rack deformation. If the canister fell the maximum height possible, 2 ft, and then toppled over, the 1-ton canister would first be stopped by the canisters it impacted and the rack surface. The canister would then rotate over until it became horizontal. The 1-ton weight, acting at the canister center of gravity, would fall approximately 5-1/2 ft. The force of this fall would act over the full 11-ft length of the canister, which would land vertically on top of several other canisters. The canisters are slightly higher than the storage rack surface and, therefore, they would absorb most of the impact force. Because the canisters are strong columns, damage to the storage rack would be minimal.

For the floor well racks in the fuel handling cave, only preliminary, unpublished analyses of the effects of dropping heavy objects have been performed. However, these preliminary analyses indicate that a drop of a 2,000 lb canister could result in failure of some floor well rack welds. There are several reasons for this more severe damage. The wider spacing of floor wells versus that of canisters in the storage area would allow the dropped canister to impact the rack surface (cave well floor) directly. There is also a greater possible drop height in the fuel handling cave. Because of the potential reduction in floor well spacing, storage area criticality analyses would not envelope the fuel handling cave scenarios. For this reason, the fuel handling cave, outside of the transfer car, is limited to the contents of two fully loaded storage canisters, unless a CSE specifically considers this scenario. The fuel handling units involved may be divided among several floor wells. (Note that this limitation does not affect fuel in a cask or other container in the transfer car.) With this limitation in place, any drop scenarios are again enveloped by the storage area analyses. The related criticality scenarios are discussed in Subsection 8.6.1.4.

Dropping a heavy weight on a storage position containing fuel could have an adverse effect on the fuel in storage, including causing a change in floor well rack position spacing. Because the structural effect of dropping a heavy object on the storage or floor well rack or on canisters has not been analyzed, suspending or moving the shield plug removable section and the lid of a cask above a storage position containing fuel is prohibited.

Dropping a heavy load, such as the cask lid or a basket/bucket, onto the cask from which it is being removed, could potentially damage the load path between the cask and the transfer car. The result of which, is that the open cask could fall to the floor of the transfer car pit and spill its radioactive and fissile material contents. This is the same accident scenario discussed near the end of Section 8.1.1, where the initiator is a design basis seismic event. The actual consequences of this event are different for each fuel-loaded cask, but it is conservatively assumed that the event could result in direct radiation exposure or radioactive material release regardless of the cask or fuel. Therefore, the INEEL hoisting and rigging program is relied upon to sufficiently reduce the likelihood of the radioactive material exposure events. Criticality safety analysis and assurance of the double contingency principle is presented in the cask-specific safety analysis for the handling operations at IFSF. The necessary controls are derived in those analyses.

8.5.4 Short-Term (<22 days) and Long-Term Coolant Flow Loss

In the event of a short-term loss of coolant flow, the fuel temperature would rise. However, an oxidation reaction or other damage to the stored fuel would not occur because even a limited airflow would provide sufficient cooling to maintain graphite fuel centerline temperatures below 1,100°F (866 K) and the ATR fuel temperature below 482°F (523 K) for many days and would provide sufficient time to permit corrective action to be taken.

Heat transfer analyses have been performed on the stored fuel (see Subsection 8.2.1). Briefly, the analyses show that, for the design cooling airflow rate of 12,000 ft^3/min, the maximum fuel element centerline temperature is 648°F (615 K) for the hottest Fort St. Vrain element and the exit air temperature for a filled facility is 119°F (321 K), based on an 80°F inlet air temperature. The studies further show that, upon a total loss of coolant, 30 days would be available in which to take corrective action before the centerline temperature of any graphite fuel element reaches 1,100°F (866 K). For the hottest canister containing fuel canned in the canning station, 22 days would be available before the fuel temperature would reach 482°F (523 K).[25,27,28]

Three thermocouples are on the storage rack, six on facility walls, and two in the outlet air stream. These are capable of measuring the temperature in these areas and giving valuable information in the event of a loss of cooling airflow and subsequent recovery. Failure to restore cooling airflow within 22 days is unlikely because (1) the system has several backup exhaust blowers and (2) two independent off-site power sources are available. Therefore, long-term loss-of-coolant airflow is unlikely. See Section 8.6.2 for a detailed discussion of cooling air flow.

8.6 Accidents

Events that could potentially have serious consequences to workers or to the public are discussed in the following subsections.

8.6.1 Nuclear Criticality Safety

The criticality safety of the IFSF operation is determined by assessing the calculated k-effective (k_{eff}) values for the process configurations of fissile material (normal and accident cases) against an established set of criticality safety criteria. These criteria, which are contained in DOE Order 420.1 and the INEEL Criticality Safety Program Requirements Manual,[45] follow:

1. For systems where the margin of safety is determined by analytical modeling, the maximum allowable k_{eff} value is 0.95 under single failure conditions. This value must include the bias of the calculational method, the statistical uncertainty when using Monte Carlo methods, and the effects of equipment tolerances, corrosion, and manufacturing uncertainties.

2. Process design and controls shall be established to require the occurrence of at least two unlikely, independent and concurrent changes (contingency failures) in process conditions before a criticality accident is possible.

3. Protection against accidental criticality shall be provided by either the control of two independent process parameters (which is the preferred approach, if practical) or a system of multiple (at least two) controls on a single parameter.

4. To be considered critically safe by mass alone, a system must not have more than 75% of the critical mass assuming the system is in its most reactive credible state. If overbatching is credible, 45% of the critical mass shall be used.

It is also INTEC policy to employ physical barriers whenever possible rather than to rely solely on administrative controls to prevent criticality accidents.

The fire-fighting designation, "No Water Permitted," is required for both the IFSF fuel handling cave and the fuel storage area whenever fuel is handled or stored in the facility. The use of this fire-fighting designation reduces the probability of a criticality occurring through moderator (water) accumulations.

The following discussion summarizes the basis for concluding that the fuels presently handled and stored at the IFSF are critically safe when the facility is operated in accordance with previously approved handling and storage methods. Addendum A to this SAR provides further information on the criticality safety in the unshielded area of the cask receiving area (south truck bay). Addendum B to this SAR provides further information on the criticality safety of fuels processed in the canning station.

8.6.1.1 Fuel Storage. At the IFSF, criticality safety during storage is maintained by controlling geometry, moderation, and fissile material mass. Implementation of controls on these parameters is provided by (1) a geometrically favorable rack, (2) design (exclusion of water lines in the storage area, etc.), (3) administrative procedures, and (4) approved storage configurations for each fuel type.

An approved storage configuration is an allowable fuel loading in a storage canister that will ensure a k_{eff} of <0.95 for the storage array under all credible single failure conditions. The configurations provide criticality control by limiting the mass of fuel allowed in any one container. In the IFSF, an approved configuration must be used in conjunction with moderator controls for some fuels to ensure criticality safety. Water flooding below and between the storage array of canisters is critically safe.[46] Water in sufficient quantities in canisters containing Rover-type fuels may not be critically safe. A single fully loaded canister containing Rover UBM in an approved configuration is critically safe even when flooded as long as the cans remain dry inside.[47,48] Moderator restriction in the facility's fuel storage area also minimizes the possibility of a criticality caused by a fuel-water reaction.

The IFSF is designed to prevent flooding or leakage of water into the handling cave and the storage area. The facility walls were built using water stop barriers between concrete lifts. Though water entry into the storage area may be possible through the expansion joint between the storage area walls and the floor edges, accumulation of a significant amount of water in the storage area is unlikely, as shown in Subsection 8.5.1.

The unlikely occurrence of a seismic event of sufficient magnitude to cause cracking, coupled with the availability of water at the crack location, would be necessary to allow water leakage through the wall. A large quantity of water would be necessary to cause significant flooding (5,000 gal would just reach the bottom of the storage canisters in the fuel storage area). The storage area has three drains connected to a drain header that has a block valve. The block valve is maintained in a locked-open position whenever fuel is stored. The drains have not been tested since the facility became operational. Even if the drains are corroded, they would still remove water from the facility. Additionally, procedures for operating the facility require inspection for water on a daily basis.

A video inspection of some areas underneath the storage racks revealed no indication that significant water leakage has ever occurred. One of the three drains was observed in the video, and it appeared to be clear of obstructions. A thin dust layer and small debris particles (such as weld slag) appeared to be present on the floor.

Evaluations were also made of the criticality hazard from partial water moderation between the canisters in the fuel storage area. These evaluations concluded that partial water moderation caused by humidity sources is not a problem.[49,50]

Compression of the entire storage rack to less than 84% of the original storage canister spacing is required before a criticality is possible (see Table 8-3, Case 20). The DBE will not cause such deformation (see Subsection 8.1).

Table 8-3. Criticality calculations.

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
1. Determine the k_{eff} for the Irradiated Fuel Storage Facility (IFSF) storage rack completely filled with Rover fuel canisters.	630 steel storage canisters (18 in. in diameter by 132 in. long) are modeled on a 24-in. center-to-center spacing, in a triangular pitch, and arrayed in alternate rows of 17 and 18 storage canisters in each row. Each canister contains two steel canister inserts in tandem (16 in. in diameter by 53.75 in. long) and each insert contains 15 Rover tubes. Each Rover tube is fabricated of cardboard (2.75 in. in diameter by 53.75 in. long) and is equipped with wooden end plugs. Each cardboard tube contains 840 g of U-235, 58 g of U-238, and 6,000 g of carbon. Each canister contains a maximum of 25.2 kg of U-235. The canister array is reflected with a close-fitting full concrete reflector on five sides and a full concrete reflector separated by 10 ft on the sixth side (top side of the array). Metal tubes with metal/rubber plugs are enveloped by cardboard tubes with wooden plugs.	0.998	Fast-09-90[49] NRRT-N-90-023[51] INEEL/INT-98-00978[52]
2. Determine the k_{eff} for the IFSF storage rack completely filled with Peach Bottom fuel canisters.	Canister size, array, and array reflection as in Case 1. Each canister contains 19 fuel elements (12 fuel elements are allowed). Each fuel element contains 291 g of U-235, 15 g of U-238, 1,560 g of Th-232, and 8,550 g of carbon in the fuel compact and additional carbon to represent the upper and lower reflector and the sleeve components. Each canister contains a maximum of 5.5 kg of U-235.	0.830	Fast-09-90[49] NRRT-N-90-023[51]
3. Determine the k_{eff} for the IFSF storage rack completely filled with Fort St. Vrain (FSV) fuel canisters.	Canister size, array, and array reflection as in Case 1. Each canister contains four fuel elements. Each fuel element contains 1,310 g of U-235, 78 g of U-238, 11,250 g of Th-232, and 111,300 g of carbon. Each canister contains a maximum of 5.2 kg of U-235.	0.656	Fast-09-90[49] NRRT-N-90-023[51]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
4. Determine the k_{eff} for the IFSF storage rack completely filled with Tory IIC fuel canisters.	Canister size, array, and array reflection as in Case 1. Each canister contains two steel canister inserts in tandem (16 in. in diameter by 42 in. long) and each insert contains 15 Tory IIC tubes. Each Tory IIC tube is fabricated of aluminum (2.75 in. in diameter by 52.75 in. long) with a wall thickness of 0.035 in. Each aluminum tube contains 127 g of U-235 and 2,511 g of beryllium oxide, which is based on the average tube loading of the highest loaded storage canister. Each canister contains a maximum of 3.8 kg U-235.	0.267	Fast-09-90[49] NRRT-N-90-023[51]
5. Determine the k_{eff} for BER-II TRIGA fuel elements in a neutronically infinite array in the IFSF storage rack. Also determine the k_{eff} for handling the fuel elements outside of approved storage.	Steel canisters (18 in. diameter by 132 in. long) each with two canister inserts (16 in. in diameter by 42 in. long) are modeled as a close-packed, square-pitch, neutronically infinite array. Each canister contains 18 fuel elements (nine elements per insert). Each canister contains a maximum of 9.5 kg of U-235.	0.564	Fast-10-82[53] WGM-03-82[54]
6. Determine the k_{eff} for 60 Rover fuel canisters in a most reactive commingled array of approved fuels (except canning station fuels) in the IFSF storage rack with optimum moderation between the storage canisters.	Canister size, arrangement, and array reflection as in Case 1. The array consists of 60 Rover fuel canisters (most reactive) contained in 76 Peach Bottom canisters (second most reactive), with the balance of the storage rack filled with FSV canisters (third most reactive). The storage canisters are loaded as described in Cases 1, 2, and 3 above. Optimum moderation between storage canisters occurs at 1.0% water volume fraction.	0.898	Fast-09-90[49] NRRT-N-90-023[51]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
7. Determine the k_{eff} for 126 Rover fuel canisters in a most reactive commingled array of approved fuels in the IFSF storage rack with optimum moderation between the storage canisters.	Canister size and array reflection as in Case 1. The array consists of 126 Rover fuel canisters contained in 504 Peach Bottom canisters. The storage canisters are loaded as described in Cases 1 and 2 above. The interstices between the canisters are filled with 1.0% water volume fraction.	0.933	Fast-09-90[49]
8. Determine the k_{eff} for a canister containing FSV fuel lying on top of an array of Rover fuel canisters in the IFSF storage area.	Steel canisters (18 in. in diameter by 132 in. long), each with two canister inserts (16 in. in diameter by 42 in. long) containing Rover fuel, in a 24-in. center-to-center triangular-pitch storage array. A steel canister containing four FSV fuel elements is modeled lying horizontally on top of lids of the Rover fuel canisters. The storage canisters are loaded and the array reflection is as described in Cases 1 and 3 above.	0.916 (for the same configuration without the FSV canister on top results in 0.924 k_{eff}. (The difference in results is a statistical anomaly of the code and is insignificant.)	JAE-33-79[55] NRRT-N-88-035[56]
9. Determine the k_{eff} for a single reflected canister containing FSV fuel.	The canister contains four fuel elements and has an infinite water reflector.	Canister dry: 0.397 Canister flooded: 0.659	ICP-1052[57]
10. Determine the k_{eff} for a single reflected canister containing Peach Bottom fuel.	The canister contains 12 fuel elements and has an infinite water reflector.	Canister dry: 0.407 Canister flooded: 0.812	ICP-1052[57]
11. Determine the k_{eff} for a water-reflected sphere containing 18 kg of U-235 as Rover fuel.	The fuel is modeled as a water-reflected sphere with moderation equivalent to the mass of 12 hands (six people).	0.920	JAE-7-77[58] RCM-02-84[59]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
12. Determine the k_{eff} for a flooded canister in an array of dry canisters of Rover fuel in the storage rack.	Canister size as in Case 1. Each canister contains two inserts (16 in. in diameter by 42 in. long). Each canister contains 30 cardboard tubes (15 tubes per insert). Each tube is loaded as described in Case 1 above. The array is triangular pitched and has a 24-in. center-to-center spacing. The interstices between canisters of the array are dry. The array is reflected with a close-fitting concrete reflector on two sides and the canister bottoms, and is unreflected on the remaining three sides.	One flooded canister: 0.998	Fast-13-88[60]
13. Determine the k_{eff} for flooded canisters of Tory IIC fuel in the IFSF storage rack.	Canisters size, arrangement, and array reflection as in Case 1. Each canister contains two canister inserts (16 in. in diameter by 42 in. long). Each canister contains 30 aluminum tubes as described in Case 4.	0.877	Fast-02-91[61] NRRT-N-90-056[62]
14. Determine the k_{eff} for arrays of fuel with flooding between the canisters.	Canisters size and arrangement as in Case 1. Rover fuel and Tory IIC canisters contain two inserts (16 in. in diameter by 42 in. long). Each canister contains any of the following: four FSV fuel elements, 12 Peach Bottom fuel elements, 30 Tory IIC cans, or 30 Rover tubes. The canisters are dry inside but the interstitial regions between canisters are flooded with water. The arrays are reflected with close-fitting concrete on two sides and the canister bottoms, and are unreflected on the remaining three sides.	FSV: 0.240 Peach Bottom: 0.351 Tory IIC: 0.329 Rover fuel: 0.339	Fast-13-88[60] RRJ-14-88[63]
15. Determine the k_{eff} for an array of FSV fuel compacted from its normal volume in canisters.	Canister and arrangement as in Case 1, except a 10 × 9 array of canisters. Each canister contains four fuel elements, compacted to 90% and 70% of their original "normal" volume, and a normal case for comparison.	Normal: 0.573 Compacted to 90%: 0.680 Compacted to 70%: 0.728	NRRT-N-88-035[56] Fast-13-88[60]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
16. Determine the k_{eff} for an array of Peach Bottom fuel compacted from its normal volume in canisters.	Canister size and arrangement as in Case 1, except with a 10 × 9 array of canisters. Each canister contains 12 fuel elements compacted to 90% of their original "normal" volume, and a normal case for comparison.	Normal: 0.757 Compacted to 90%: 0.785	NRRT-N-88-035[56] Fast-13-88[60]
17. Determine the k_{eff} for handling Peach Bottom fuel elements outside of approved storage in the IFSF.	Uncontained fuel elements are modeled in a close-packed, square-pitched, 10 × 10 × 1 array in the corner of a concrete room. The array is reflected with close-fitting concrete on two sides and the bottom and a concrete reflector separated by 10 ft on the remaining three sides.	0.887	ICP-1052[57] WGM-7-75[64]
18. Determine the k_{eff} for handling FSV fuel elements outside of approved storage in the IFSF.	Uncontained fuel elements are modeled in close-packed, square-pitched, 5 × 5 × 1 or 5 × 5 × 2 arrays in the corner of a concrete room. Each array is reflected with close-fitting concrete reflector separated by 10 ft on the remaining three sides.	5 × 5 × 1 array: 0.593 5 × 5 × 2 array: 0.788	ICP-1052[57] WGM-7-75[64]
19. Determine the k_{eff} for handling Tory IIC fuel outside of approved storage in the IFSF.	Fuel cans are modeled in close-packed, square-pitched, 6 × 6 × 1, 7 × 7 × 1, or 8 × 8 × 1 arrays. Each can contains 753 g of U-235 at a packing factor of 0.7 and a BeO/U-235 atomic ratio of 116. The arrays are reflected with close-fitting concrete on two sides and the bottom side, and a water reflector separated by 12 in. on two sides and by 31.4 in. on the top side.	36 cans: 0.840 50 cans: 0.930 63 cans: 1.00	JAE-11-77[65] WGM-04-77[66]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
20. Determine the k_{eff} for a reduced storage canister spacing caused by earthquake-induced failure of the storage rack. No water moderation between canisters.	Storage canister size, arrangement, and array reflection as in Case 1. The array consists of 60 Rover fuel canisters (most reactive fuel) surrounded by 76 Peach Bottom canisters (second most reactive) with the balance of the storage rack filled with FSV canisters (third most reactive). Each canister contains either 30 Rover tubes (15 tubes per insert), 12 Peach Bottom fuel elements, or four FSV fuel elements. The storage canisters are loaded as described in Cases 1, 2, and 3 above.	1.0 area fraction[b]: 0.872 0.918 area fraction: 0.918 0.840 area fraction: 0.978	Fast-10-90[67] RRJ-10-90[68]
21. Determine the k_{eff} of fully loaded single canisters of the fuels to be processed in the canning station, and of FSV, Rover fuel, and Peach Bottom fuels.	The canisters are loaded with the respective fuels. The canisters are modeled both dry inside-fully reflected, and flooded inside-fully reflected. Calculations for MURR envelop all aluminum plate fuels: ATR, HFBR, ORR, ARMF, CFRMF, and BMI-Spec.	Fuel type — k_{eff} (dry) — k_{eff} (flooded) Rover fuel — 0.325 — 1.016 FSV — 0.261 — 0.766 MURR — 0.281 — 0.811 ATR — 0.262 — 0.739 ARMF/CFRMF — 0.158 — 0.562 TRIGA-Al — 0.559 — 0.897 BER-II TRIGA — 0.229 — 0.836 Peach Bottom — 0.407 — 0.898 BMI-Spec/ WAPD/CFRMF Core Filter — 0.713 — 0.886	INEL-96/096[69]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
22. Determine the k_{eff} of square arrays of 95 canisters with each containing one type of fuel, dry.	The canisters are loaded with the fuel types shown in Column 3. The canisters are arrayed in triangular pitches of 24 in. (normal) and 22.5 in. (reduced spacing). The array is reflected 2 ft of concrete against four sides and the bottom, and 10 ft above. No water is inside or between canisters.	Fuel type	k_{eff} (24 in.)	k_{eff} (22.5 in.)	INEL-96/096[69]
		Rover fuel	0.886	0.986	
		FSV	0.659	0.705	
		ATR	0.454	0.469	
		MURR	0.505	0.523	
		ARMF/CFRMF	0.242	0.249	
		TRIGA-Al	0.853	0.881	
		Peach Bottom	0.825	0.886	
		BER-II TRIGA	0.449	0.479	
23. Determine the k_{eff} of two canisters of MURR and TRIGA-Al fuels lying on top of an array of Rover fuel canisters in the storage area.	Rover fuel canisters and loadings are as described in Case 1. An array of 95 Rover fuel canisters having 22.5-in. triangular-pitch spacing was modeled. A close-fitting 2-ft-thick concrete reflector is on four sides at the bottom, and separated by 10 ft on top. Two canisters of MURR or TRIGA-Al fuels were placed horizontally on top of the array. Dry conditions are assumed.	Description		k_{eff}	INEL-96/096[69]
		Array only - no fuel on top		0.936	
		Array with 1 MURR on top		0.935	
		Array with 2 MURR on top		0.939	
		Array with 2 TRIGA-Al on top		0.933	
		Array with 2 TRIGA-Al on top, next to concrete		0.932	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)	Criticality Safety Evaluation References[a]
24. Determine the k_{eff} of 95 Rover fuel canisters in a square array having a reduced spacing triangular pitch and varying degrees of moderation.	Rover fuel canisters and loadings are as described in Case 1. Triangular pitch array of 22.5-in. degree of moderation between canisters (water volume fraction) per tabulation.	wvf / k_{eff}: 0 (dry): 0.936 0.01: 0.939 0.03: 0.940 0.05: 0.925 0.1: 0.881	INEL-96/096[69]
25. Determine the k_{eff} of the most reactive possible array of fuels previously approved for storage in the IFSF.	The most reactive array consists of 20 Rover-type fuel canisters, surrounded by 36 TRIGA-Al canisters (selected because TRIGA-Al, the most reactive fuel to be canned in the Fuel Canning Station, envelops all canning station fuels), surrounded by 71 Peach Bottom canisters, surrounded by FSV fuel filling the remainder of the IFSF. The array is modeled dry with normal (24-in.) spacing, dry with minimum (22.5-in.) spacing, and with minimum spacing and 3.0% water volume fraction (most reactive moderation condition) between canisters.	k_{eff} Normal Spacing: 0.891 k_{eff} Minimum Spacing: 0.940 k_{eff} Minimum Spacing with 0.03 wvf: 0.942	INEL-96/096[69]
26. Determine the k_{eff} of the contents of one Rover fuel type canister, spilled on the floor beneath the storage rack in an array with two other Rover fuel canisters.	The contents of three loaded canisters are modeled as a hemisphere with the concrete floor reflector. This model envelops an array formed if a single Rover fuel canister were dropped and the contents came out and spilled to the bottom of a storage rack position. The contents could then form a pile tangent to the nearest two Rover fuel-containing canisters in the storage rack. Rover-type fuels envelop all other graphite fuels.	k_{eff} 0.730	INEL-96/096[69]
27. Determine the k_{eff} of the contents of one spilled canister of TRIGA-Al fuel in a hemisphere on the floor.	The contents of one TRIGA-Al canister, at fuel rod design density, is modeled as a hemisphere on the concrete floor.	k_{eff} 0.932	INEL-96/096[69]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
28. Determine the k_{eff} of an array of the contents of one spilled canister of TRIGA-Al fuel among intact canisters containing ROVER-type fuel in the storage rack.	The contents of one TRIGA-Al canister, at fuel rod design density, is modeled as a hemisphere on the concrete floor. An array is formed having two pairs of intact Rover fuel canisters touching the hemisphere. The Rover fuel canisters of each pair are touching each other and the pairs are on opposite sides of the TRIGA-Al hemisphere. The pairs are tangent to the hemisphere. The array is reflected on the bottom by the concrete floor.		k_{eff} 0.944		INEL-96/096[69]
29. Determine the k_{eff} of an array of the contents of one spilled TRIGA-Al canister among canisters containing TRIGA-Al fuel in the storage rack.	The contents of one TRIGA-Al canister, at fuel rod design density and at 90% theoretical density, is modeled as a hemisphere on the concrete floor. An array is formed having two intact TRIGA-Al fuel canisters touching each other and both tangent to the hemisphere. The array is reflected on the bottom by the concrete floor. The array is modeled with and without concrete reflection on one side to account for the possibility of this configuration forming at the edge of the rack, against the facility wall. The fuel rod design density cases are reported for information, but the 90% density cases are conservative given that the form of the fuel precludes dense packing.		k_{eff} in storage rack	k_{eff} against the wall	INEL-96/096[69]
		Hemisphere with full theoretical density	0.940	0.955	
		Hemisphere with 90% density	0.890	0.906	
30. Determine the k_{eff} of one fully loaded Rover UBM bucket.	The bucket is maximally loaded with 6 cans of enveloping Rover UBM. The cans are in the most reactive position toward the center of the bucket which is still within the confines of the bucket positioning. No water internal to any can.	Reflection / moderation between cans	None/ none	0.207	INEL/INT-97-00766[47]
			Water/ water	0.693	INEEL/INT-97-01024[48]
			Concrete/ none	0.697	
			concrete/ water	0.762	
			lead/ water	0.790	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
31. Determine the k_{eff} of 2 adjacent fully loaded Rover UBM buckets.	The buckets are side-by-side and touching, with buckets loaded as in the preceding (No. 30). Similar calculations done with spacing between buckets increased in one-in. increments showed that reactivity decreased with spacing between buckets. Models all included concrete reflection.	Dry		0.705	INEL-96/269[70]
		Water reflection		0.855	
		Water reflection and moderation between cans		0.950	
32. Determine the k_{eff} of one spilled and one intact Rover UBM bucket.	Cans are loaded as previously stated (No. 30). Cans remain intact, but spilled from one of the 2 buckets. The intact bucket was assumed to have cans placed as near each other as possible (the most reactive arrangement), while still remaining in their intended bucket compartments. Cases all included concrete reflection.	6 cans closely stacked on top of intact bucket	No water inside cans.	0.589	INEL-96/269[70]
			Full water reflection and modera-tion between cans.	0.924	
		6 cans arranged in annulus around intact bucket	No water inside cans.	0.786	
			Full water reflection and modera-tion between cans.	0.983	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
33. Determine the minimum critical number of Rover UBM cans for various conditions.	All cases have concrete corner reflection. Cans are assumed loaded with enveloping Rover UBM for each set of conditions listed below:		No. of cans for $k_{eff} + 2\sigma \geq 1.00$	No. of cans for $k_{eff} + 2\sigma \leq 0.95$	INEEL/INT-97-00766[47] INEEL/INT-97-01024[48]
	Dry.		24	19	
	Water reflection, water between cans.		14	11	
	Optimum internal moderation in cans, water reflection and moderation between cans.		2	1	
34. Determine the maximum k_{eff} of 7 fully loaded Rover UBM canisters.	The maximum number of Rover UBM canisters is estimated to be 7. Scoping calculations in the referenced CSE show that the k_{eff} is unaffected by modeling the 12 cans in two separated tiers of 6 cans each or in extending the cans the full length of the canister. Hence, all canister models use 6 double-length cans. The CSE considered both linear and hexagonal arrangements of 7 canisters in the storage area. All arrangements were dry with concrete reflection and assume enveloping canister contents for the respective arrangements. K_{eff} values for the same canister arrangement without concrete reflection are less than half those reported here with concrete reflection.		Max. k_{eff}		INEEL/INT-97-00766[47] INEEL/INT-97-01024[48]
		Linear arrangements of 7 canisters	0.819		
		Hexagonal arrangements of 7 canisters	0.923		

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)		Criticality Safety Evaluation References[a]
35. Determine the maximum k_{eff} of 6 fully loaded Rover UBM canisters stored in the fuel storage area with other IFSF-approved fuels.	Linear and hexagonal arrangements of Rover UBM canisters were put into the full IFSF storage array containing the five original fuels, the 8 canning station fuels (including ARMF/CFRMF), plus EBR-II and MTR Canal (planned future fuels). The models of INEL-96/096 and INEL-96-362 were used for these fuels.	Current/planned storage array for other fuels listed at left plus 6 Rover canisters loaded as above	Maximum positional k_{eff}= linear 0.892 hexagonal (7 canisters) 0.906	INEL-96/269[70] INEL-96/096[69] INEEL/INT-97-00766[47] INEEL/INT-97-01024[48] INEL-96/362[71]
		Current/planned storage array for other fuels listed at left, plus 6 Rover UBM canisters loaded with enveloping Rover UBM and in planned location (Row 3, Positions A-F)	0.866	
		Current/planned other fuels listed at left, plus 6 Rover canisters loaded into the most reactive storage array as described in Case 25 above	Maximum keff≥ 1.002	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)		Criticality Safety Evaluation References[a]
36. Determine the k_{eff} of one fully loaded Rover UBM canister.	The Rover UBM canister is flooded and is fully loaded with 12 Rover UBM cans, which are also flooded.	With can separation in bucket as small as possible given bucket geometry	≥1.037	INEL-96/269[70] INEEL/INT-97-00766[47] INEEL/INT-97-01024[48]
	The Rover UBM canister and the 12 Rover UBM cans are dry inside and outside. The can separation in bucket is as small as possible, given bucket geometry (most reactive within-bucket configuration).	No concrete reflection	0.215	
		With concrete reflection	0.688	
	The Rover UBM canister is flooded, but loaded with 12 cans, which are dry inside. The can separation in bucket is as small as possible, given bucket geometry (most reactive within-bucket configuration).	No concrete reflection	0.650	
		With concrete reflection	0.727	
37. Twelve Rover UBM cans spilled out of canister and bucket into the storage array.	Canister fails and intact cans drop into the dry storage array. The planned array k_{eff} is 0.866 (Case 35, above). The maximum increase in k_{eff} is calculated to be 0.038.		0.904	INEL-96/269[70] INEEL/INT-97-00766[47] INEEL/INT-97-01024[48]

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
38. Determine the minimum critical number of Rover fuel tubes.	Contents of tubes are rubblized. Tubes and contents are in most reactive configuration. Maximum of 600 g U-235 per tube. (Actual Rover fuel tubes now in storage have a maximum of 480 g U-235 per tube).	All dry	110 tubes	k_{eff}=0.920	INEEL/INT-98-00978[52]
			118 tubes	0.947	
			127 tubes	0.970	
		Flooded completely	4 tubes	k_{eff}=0.903	
			5 tubes	0.974	
			6 tubes	1.038	
	Tubes contain intact elements. Tubes and contents are in most reactive configuration. Maximum of 600 g U-235 per tube. (Actual Rover fuel tubes now in storage have a maximum of 480 g U-235 per tube).	Flooded completely	7 tubes	k_{eff}=0.836	INEEL/INT-98-00978[52]
			10 tubes	0.939	
			12 tubes	0.998	
			15 tubes	1.067	
	Contents of tubes are rubblized. Tubes and contents are in most reactive configuration. Maximum of 480 g U-235 per tube (Actual maximum for Rover fuel tubes now in storage).	Flooded completely	4 tubes	k_{eff}=0.890	INEEL/INT-98-00978[52]
			5 tubes	0.961	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
39. Determine the k_{eff} of Rover fuel tubes in Rover UBM insert adapter in transfer car.	Fuel tubes in one adapter port, no additional configuration control. Fuel may be rubblized inside tubes. Maximum of 600 g U-235 per tube.	110 tubes, dry		k_{eff}=0.920	INEEL/INT-98-00978[52]
		4 tubes, flooded		0.903	
		5 tubes, flooded		0.974	
		6 tubes, flooded		k_{eff}>1.000	
	8 fuel tubes in a Rover fuel transfer device in each adapter port; 16 fuel tubes total. Within the transfer device, fuel tubes are temporarily sleeved in open 3.5-in. diameter Al tubes. Each sleeved fuel tube is placed into one of the 45 degree (± 2 degree) sectors of the transfer device. Fuel may be rubblized inside tubes. Maximum of 600 g U-235 per tube. (Actual Rover fuel tubes now in storage have a maximum of 480 g U-235 per tube.)	Dry	Transfer device center to edge of nearest tube:	k_{eff}=0.489	
			2.87 in.	=0.447	
			3.50 in.	=0.436	
			3.74 in.	=0.429	
			4.09 in.		
		Ports are flooded completely, both inside and outside of open Al sleeve tubes used to contain fuel tubes within transfer device. Dry between ports	2.87 in.	k_{eff}=0.930	
			3.50 in.	=0.840	
			3.74 in.	=0.816	
			4.09 in.	=0.771	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)			Criticality Safety Evaluation References[a]
39. (Continued) Determine the keff of Rover fuel tubes in Rover UBM insert adapter in transfer car.	8 fuel tubes in a Rover fuel transfer device in each adapter port; 16 tubes total. Within the transfer device, fuel tubes are temporarily sleeved in open 3.5-in. diameter Al tubes. Tubes are distributed in 45 degree (±2 degree) sectors around the transfer device. Fuel may be rubblized inside tubes. Maximum of 600 g U-235 per tube. (Actual Rover fuel tubes now in storage have a maximum of 480 g U-235 per tube.)		Transfer device center to edge of nearest fuel tube:		INEEL/INT-98-00978[52]
		Flooded inside Al sleeve tubes that contain fuel tubes within transfer device; dry elsewhere (outside Al tubes)	2.87 in. 3.50 in. 3.74 in. 4.09 in.	k_{eff}=0.793 =0.701 =0.678 =0.653	
40. Determine the k_{eff} of Rover fuel tubes in an infinite array of 6M drums in cask receiving area.	Close-packed array of 6M drums with 2R liners. Concrete reflection above and below drums. Each drum loaded with 4 cardboard or stainless-steel 2-in. Rover fuel tubes. Each tube contains Rover fuel with 600 g U-235. Fuel inside tubes may be rubblized.	All drums closed, dry inside		k_{eff}=0.267	INEEL/INT-98-00978[52]
		One drum in each 2×3 sub-array is open and flooded inside 2R container		k_{eff}=0.853	
		All 2R containers are open and flooded inside		k_{eff}=0.860	

Table 8-3. (continued).

Case	Assumptions and Bases	Calculated Results (k_{eff} + 2 standard deviation + applicable bias)		Criticality Safety Evaluation References[a]
41. Determine the k_{eff} of a 3×2 array of 6M drums containing 4 Rover fuel tubes each, with additional Rover fuel tubes spilled on the drum array.	Close-packed array of 6M drums with 2R liners. Concrete reflection above, below, and on all 4 sides of drum array. Each drum loaded with 4 cardboard or stainless-steel 2-in. Rover fuel tubes. Each tube contains Rover fuel with 600 g U-235. Fuel inside tubes may be rubblized. All 2R containers are flooded inside. Array is concrete-reflected on all 6 sides.	15 Rover fuel tubes spilled between drums in the array	k_{eff}=0.859	INEEL/INT-98-00978[52]
		One Rover fuel tube spilled on top of drums in the array	k_{eff}=0.855	
		One additional Rover fuel tube is between outside wall and 2R liner of a 6M drum in the array	k_{eff}=0.856	

8.6.1.2 Fuel Handling. Fuel handling in the IFSF is necessary for (1) transferring fuel between shipping casks and storage canisters, (2) preparing fuel elements for storage, (3) transferring fuel into and out of the canning station, and (4) transferring fuel between the handling cave and the storage area. When these operations are performed, the configuration control provided by the physical limitations of the shipping casks or the fixed position storage racks is lost. Therefore, handling requirements are necessary to ensure criticality safety by imposing restrictions on mass and moderator and by limiting the opportunities for neutron interaction among different types of fuel. These requirements are based on criticality safety evaluations (CSEs), which determine the U-235 mass of each fuel allowed out of approved storage, to prevent a k_{eff} of 0.95 from being exceeded after any single failure.

Criticality control during temporary storage in the cave wells in the fuel handling cave is maintained by (1) administrative controls that limit the amount of fuel that can be stored in any one well, (2) the cave-well spacing, which is greater than the spacing of the permanent storage racks, and (3) moderator control in the handling cave. To provide criticality control when fuels approved for storage at the IFSF are outside of approved permanent or temporary storage locations, a fuel handling unit (FHU) has been designated for each fuel. The FHU is an amount of each fuel allowed out of approved storage that can be safely handled without configuration control, but with moderator control. An FHU may be in the form of a fuel element, a storage canister containing fuel, or a basket or bucket containing fuel. FHUs are designated for each type of fuel approved for the IFSF. Only one FHU may be out of permanent or temporary storage at one time. In addition to the physical limitations and the use of FHUs, criticality is further prevented by specifying the areas in which fuel can be temporarily positioned, the moderator restrictions for each fuel, and the types of fuel that can be in the fuel handling cave simultaneously.

Moderator control for the fuel handling cave is required because sufficient water intrusion into a single canister of Rover fuel could potentially cause a criticality (see Table 8-2, Case 12). To ensure that no accumulation of water occurs in the cave wells through ceiling leaks or other structural faults, the cave-well drain valves and header valve are maintained in a locked-open position whenever fuel is present. The fuel handling cave floor does not have drains. If sufficient water were to accumulate in the handling cave, the water would overflow into the shuttle-bin pit, the roughing-filter plenum, or the cave wells, which have drains. If water seeped into a cave well, the water would drain out the cave-well drain. Any water between cave wells would provide neutron isolation between cave wells and would decrease the rack array k_{eff}.

Significant quantities of water may be brought into the handling cave during transfer of fuels into the Fuel Canning Station. Because of the possibility of spilling this water, only specifically analyzed fuel configurations are allowed in the cave for canning station operations. Fuels being processed in the canning station may, in some cases, have more than one type of fuel in a given canister. Any fuels approved for storage in a single canister have been analyzed and shown to be critically safe. If any water is present in the canning station drip pans, it must be removed from the fuel handling cave or allowed to dry before additional fuel is brought into the cave.

A water line passes through the crane maintenance area to a safety shower in the hallway outside the crane maintenance area. The line is continuous and there are no valves within the crane maintenance area to allow water to be piped into the area. If the line were to leak, water could run into the transfer car pit and drain to the sump, but could not get into the storage area or the handling cave because the water could not get past the transfer car pit. A steam line also enters the crane maintenance area, as discussed in Subsection 5.1.2. This steam line remains disconnected outside the crane maintenance area except under controlled conditions.

A canister containing fuels not yet dried in the canning station may be removed from the canning station and placed in the shuttle bin. The shuttle bin may be moved to the storage area side of the shield wall if a personnel entry into the fuel handling cave is necessary. However, the canister shall not be removed from the shuttle bin, while on the storage area side of the wall. No other fuels may be brought into the handling cave during the operation.

Some fuels/fissile materials (such as Rover fuel and Rover UBM) may be handled outside of a closed transfer container in the CAS coverage zone, described in Section 6.1.2.3. As stated there, the restriction of these types of handling operations to this zone ensures adequate CAS coverage for such operations.

Additionally, the transite roof over the cask receiving area is assumed to fail in an earthquake, so in analyses of accident scenarios, no credit is taken for the roof as a barrier over the CAS coverage zone. For example, more than four Rover fuel tubes may not be transferred into the PCS in the transfer car without the configuration control provided by the Rover fuel transfer devices (TD-GSF-928- 1 or –2). These devices assure criticality safety of Rover fuel even if flooded. The device design is such that falling roof members would have to pierce the PCS roof and fall with sufficient force directly into the transfer device in such a way as to severely deform the device, allowing at least five of the existing Rover fuel tubes to be pushed into the most reactive configuration. Criticality could still not occur unless sufficient water/melting snow were on the failed building roof above the PCS so as to flood the Rover fuel tubes in the transfer device in the transfer car. Simultaneous occurrence of all necessary factors for such a scenario is not considered credible.

8.6.1.3 Criticality Calculations. Criticality calculations have been performed for various handling and storage configurations in the IFSF to determine the criticality safety parameters based on uranium mass, moderator, neutron interaction, and geometry. The criticality calculations are essential to the development of the criticality accident scenarios to identify those configurations of fissile materials in the process that exceed a k_{eff} of 0.95. A summary of the criticality calculations for the IFSF is presented in Table 8-2. Rover fuel criticality calculations are listed in Addendum A to this SAR. Calculations for Peach Bottom Core II fuel envelop calculations for Core I fuel, which normally is stored in CPP-749,[72] except for the one test element (PTE-1) of Core I fuel that is currently in the storage area. This PTE-1 element has a separate criticality safety evaluation.[73] The Peach Bottom Core I fuel that is being transferred from the FECF and the PTE-1 element may be handled and stored in the IFSF fuel handling cave and in the fuel storage area.[72,74] Criticality calculations for Fuel Canning Station operations and transfers are listed in Addendum B to this SAR.

Criticality calculations are used both to determine safe conditions and to identify potentially unsafe conditions that require additional controls. Not all cases from the CSEs are included in this SAR. However, those cases that are bounding or that are necessary to establish controls or to support conclusions of the SAR are included. The CSEs are, in general, more comprehensive than the limited cases reported here. K_{effs} quoted in Table 8-3 include the calculated value plus 2σ statistical uncertainty plus any applicable bias.

8.6.1.4 Criticality Accident Logic Matrix. Analyses were performed to determine the abnormal events or sequence of events that could result in possible formation of critical uranium configurations in various areas of the IFSF. The necessary conditions for criticality and the credible criticality accident scenarios are summarized in Table 8-4. As stated previously, the double-contingency criteria must be satisfied for prevention of criticality accidents.

8.6.1.4.1 Excessive Number of Fuel Elements Out of Storage—This scenario involves potential violation of fuel handling limits for fuel elements, buckets, inserts, and baskets located out of approved storage. Fuel handling limits for each type of fuel are set to prevent any single overbatching error from being able to result in a critical array. A qualified fissile material handler is responsible for compliance with fuel handling limits. Independent verification of compliance with fuel handling limits by a second qualified fissile material handler provides detection and correction, if an error

Table 8-4. Criticality accident scenarios.

Accident	Control/Failure 1	Control/Failure 2	Additional Administrative Violations	Concurrent Conditions
1. Criticality in fuel handling cave caused by having excessive fuel elements out of storage.	Failure of a certified fissile material handler to comply with fuel handling limit.	Failure of a second certified person to independently ensure compliance with limit.	Repeated violations of Controls 1 and 2.	Sufficient fuel elements assembled to form a critical array: >49 Rover fuel tubes, or >18 kg of U-235 as loose Rover fuel material; or >50 Fort St. Vrain elements; or >50 Tory IIC cans; or >100 Peach Bottom elements; or >93 TRIGA cans (most reactive canning station fuel when dry).
2. Criticality in fuel handling cave caused by having excessive fuel storage canisters outside canning station, cask, cave floor wells, and shuttle bin.	Failure of a certified fissile material handler to comply with canister out-of-storage limit.	Failure of a second certified person to independently ensure compliance with fuel canister out-of-storage limit.	Repeated failure of Controls 1 and 2.	Fuel canisters assembled in critical close-packed array: (>260 Fort St. Vrain canisters; >260 Peach Bottom canisters; > 2 Rover or Tory IIC canisters (most reactive fuels).
3. Criticality in fuel handling cave caused by addition of hydrogenous moderator material to an out-of-storage array of Rover fuel, no personnel entry.	Failure of a qualified operator to comply with restriction against moderator material being introduced into the cave while fuel is in cave.	Failure of a second qualified operator to ensure moderator is not introduced into cave while fuel is in cave.		Sufficient moderator (at least 6.7 L of water or equivalent), and this moderator enters into array of Rover fuel containing at least 18 kg of U-235.

Table 8-4. (continued).

Accident	Control/Failure 1	Control/Failure 2	Additional Administrative Violations	Concurrent Conditions
4. Criticality in fuel handling cave caused by addition of hydrogenous moderator material to an out-of-storage array of Rover fuel, with personnel entry.	Failure of a qualified operator to comply with reduced fuel out-of-storage limit and with restriction against moderator material being introduced into the cave while fuel is in cave.	Failure of a second qualified operator to ensure fuel out of storage is reduced and that moderator is not introduced into cave while fuel is in cave.	Failure to place insert containing fuel in excess of reduced limit in storage canister or cave well, and cover, or to return excess fuel to transport container, and cover, prior to personnel entry into cave.	Sufficient moderator (at least 6.7 L of water or equivalent), and this moderator enters into array of Rover fuel containing at least 18 kg of U-235.
5. Criticality in the storage area caused by water flooding of a storage canister containing Rover fuel.	Seismic event causes crack in building roof.	Leak directly above or very close to a canister for water to enter canister.		Presence of rainfall or snowmelt before leak is sealed; leak must last long enough and supply enough water to allow >19.7 L of water to accumulate in canister; canister lid will exclude some water.
6. Criticality in the storage area caused by water flooding of multiple storage canisters containing non-Rover fuels.	Seismic event causes crack in building roof.	Large leak directly above or very close to multiple adjacent canisters for water to enter canisters.	Multiple canisters ($\geq$3 of any non-Rover fuel) must be affected.	Presence of rainfall or snowmelt before leak is sealed; leak must last long enough and supply enough water to flood multiple canisters ($\geq$3) to top.
7. Criticality in storage area caused by water intrusion from undried canning station fuel placed in shuttle bin.	Failure of a certified fissile material handler to comply with prohibition of removing undried fuel canister from shuttle bin in storage area.	Failure of a second certified fissile material handler to ensure compliance with the prohibition.	Repeated failures. Water from at least three undried canisters required for a criticality.	After first failure, loading another canister into canning station verges on incredible; all failures must result in water entering the same canister in storage area.
8. Criticality in storage area caused by having excess fuel in storage canisters.	Failure of certified fissile material handler to comply with canister loading limit.	Failure of a second certified person to independently ensure compliance with canister loading limit.	Repeated violations of Controls 1 and 2.	Possible only for Rover-type fuels in Rover tubes. Several overloaded Rover canisters in storage array are required for criticality.

Table 8-4. (continued).

Accident	Control/Failure 1	Control/Failure 2	Additional Administrative Violations	Concurrent Conditions
9. Criticality in storage area caused by water entering storage canister(s) after flooding lower levels of the Irradiated Fuel Storage Facility (IFSF).	Seismic failure, external rainfall, or snowmelt causes water entry from CPP-603 Fuel Storage Basins (FSB) to flood IFSF lower levels.	Water leakage into IFSF fuel canister(s) from bottom; canisters have welded-in bottoms designed to be leak-tight; canisters have been tested on a sample basis and have been shown to be leak-tight.		Possible only for Rover-type fuel canisters in either the storage area or the handling cave floor wells. According to evaluation, massive seismic failure will not occur. Storage area drains must fail to remove water.
10. Criticality in storage area or handling cave caused by dropping a loaded fuel handling unit (FHU) on rack containing fuel; fuel remains in canister or spills out onto rack top.	Failure of engineered lifting equipment or operator error in use of equipment.	Failure of certified fissile material handlers to comply with single FHU out-of-storage limit.		Repeated failures: Any canister, bucket, or spilled fuel canister on top of a rack position is safe.
11. Criticality in storage area or handling cave caused by dropping a loaded FHU on rack containing fuel; bottom fails or lid comes off and fuel spills down into empty storage rack position.	Failure of engineered lifting equipment or operator error in use of equipment.	Failure of certified fissile material handlers to comply with single FHU out-of-storage limit.		Repeated failures: Any canister, bucket, or spilled fuel canister spilled to bottom of storage rack position, in array with other canisters, is safe.

Table 8-4. (continued).

Accident	Control/Failure 1	Control/Failure 2	Additional Administrative Violations	Concurrent Conditions
12. Criticality in handling cave caused by fuel being spilled into a cave well or the canning station containing fuel allowed in cave simultaneously.	Failure of engineered lifting equipment or operator error in use of equipment.	Dropped fuel spills from canister, penetrates cave well or canning station cover, and falls between canister and cave well or between canister and canning station.		No intact fuel element can fit in the annular space between canister and canning station or between canister and cave well; sufficient rubblizing of fuel to allow significant fuel rubble to enter annulus is not credible.
13. Criticality in handling cave caused by fuel being spilled into a cave well or the canning station containing the wrong fuel.	Failure of engineered lifting equipment or operator error in use of equipment.	Other fuels present in handling cave wells or canning station when fuel is moved, in violation of prohibition.		Canning station cover or cave-well lids are not in place, or fail to resist impact from drop.
14. Criticality in transfer car pit caused by 2 or more Rover UBM cans rolling into water-filled sump.	Failure of engineered lifting equipment or operator error in use of equipment while moving Rover UBM bucket from transfer car to storage canister in cave.	Failure of Rover transfer car insert to withstand drop of lifted bucket onto other loaded bucket in transfer car.	Failure to move first of two buckets in a path which does not pass over the second bucket.	The bucket drops into the second bucket with sufficient force to punch through the transfer car insert, at least two cans come out of the bucket and roll into the sump, and the sump contains sufficient water to cause a criticality after Rover UBM cans roll into it. Cans remain in water long enough for water to enter through gasketed closure.
15. Criticality caused when a number of fuel canisters are moved/rearranged into a critical storage arrangement.	Failure of a certified fissile material handler to comply with the approved fuel storage configurations.	Failure of a second certified fissile material handler to ensure compliance with the approved fuel storage configurations.	Failures are repeated multiple times.	The unapproved storage ports used are some of the more reactive positions with respect to possible criticality.

Table 8-4. (continued).

Accident	Control/Failure 1	Control/Failure 2	Additional Administrative Violations	Concurrent Conditions
16. Criticality in cask receiving area caused by excessive Rover UBM cans out of approved storage containers.	Failure of qualified personnel to comply with limit of one Rover UBM can that may be out of a closed 6M drum or a Rover UBM bucket in the transfer car.	Failure of a second qualified person to ensure that the limit is maintained.	Violations are repeated until at least 21 cans (dry conditions) are amassed out of approved storage configurations; OR Concurrent failures to remove any visible water from truck ramp, then repeatedly transferring 2 or more cans over ramp.	Cans are assembled into close-packed configuration. OR In the case of 2 or more cans over the truck ramp, the ramp must contain sufficient water to immerse the cans, more than one can is dropped into the water, and the cans remain immersed long enough for water to enter cans through gasketed lid closure.
17. Criticality in fuel handling cave caused by excessive Rover UBM cans out of approved storage.	Failure of qualified personnel to comply with handling requirements/limits.	Failure of a second qualified person to ensure compliance with requirements/limits.	Violations are repeated until at least 24 Rover UBM cans are amassed.	The cans are positioned into one of the closed-packed configurations most favorable to criticality.
18. Criticality in fuel storage area caused by water flooding of a storage canister containing Rover UBM.	Building roof fails.	Water/snow melt is directly above or very close to a Rover UBM canister so that water leaks or splashes on Rover UBM canister.	The canister lid is improperly installed or the wrong canister and lid type (i.e., nonwater-shedding lid) are used. Rover UBM can gasketed lids are improperly installed so that water may enter.	Sufficient water enters canister and cans so that both the Rover UBM contents inside the cans and the canister outside the cans are flooded. (A flooded canister with dry can interiors remains subcritical.)

Table 8-4. (continued).

Accident	Control/Failure 1	Control/Failure 2	Additional Administrative Violations	Concurrent Conditions
19. Criticality in transfer car in PCS caused by flooding of Rover UBM insert adapter containing Rover fuel. Transfer device(s) not used.	Failure of qualified personnel to comply with limit of 4 Rover fuel tubes in insert adapter unless Rover fuel transfer device is used.	Failure of a second qualified person to ensure that the limit is maintained.		Earthquake causes break in building roof above PCS. Earthquake also causes break in PCS roof above Rover fuel in transfer car. Sufficient water/melting snow is on building roof above Rover fuel tubes so that water floods Rover fuel tubes in Rover UBM insert adapter in transfer car.
20. Criticality in cask transfer car pit caused by a fuel-loaded cask falling from the transfer car and reconfiguring the fuel into a critical form.		See the specific safety analysis for each cask handling operation.		

is made by the first person, before a criticality is possible. Multiple repetitions of errors involving excessive fuel handling units being removed from storage would be necessary to achieve a critical array in the fuel handling cave. Except for Rover-type fuels, which can be handled by hand, there is no way, other than by intentionally placing an FHU in an unapproved location, to have more than one FHU out of approved storage at a time, because only one hoist is capable of gripping and lifting an FHU.

8.6.1.4.2 Excessive Number of Storage Canisters Out of Approved Storage—This scenario is similar to the previous one, except for involving loaded canisters containing fuel. Violation of handling limits by a certified fissile material handler, plus failure of independent verification by a second certified person to detect and correct the violation could result in having excess fuel out of approved storage. Repeated violations would be required for a criticality to occur.

Calculations shown in Table 8-3 indicate that close-packed arrays of more than 260 loaded Fort St. Vrain canisters or Peach Bottom canisters would be critical. No similar calculations are available for Rover fuel and Tory IIC canisters. However, the minimum critical number of Rover fuel tubes and Tory IIC cans in a dry array is 64 and 63, respectively. Because each canister of Rover or Tory IIC fuel contains only 30 tubes or cans, respectively, the minimum critical number of storage canisters of these fuels would be at least three. At least two canisters of all fuels processed in the canning station, in a close-packed array, are critically safe. It is physically impossible to place two canisters next to each other in a normal operational situation (no reconfiguration of approved locations). Thus, for all of the fuels stored in the IFSF, two canisters in a side-by-side array will not be critical, and at least three canisters (two violations of the approved limit) would have to be out of approved storage, beyond the handling limit of one, for a criticality to occur. Again, aside from intentionally placing a canister in an unapproved location, there is no way to have more than one container out of approved storage, because only one hoist is capable of gripping and lifting a canister.

8.6.1.4.3 ***Moderator Material Entry into the Cave While Rover Fuel Is Being Handled (No Personnel Entry)***—Most fuels stored in the IFSF are not so moderator-sensitive that water, interstitially mixed with the contents of a storage canister, would cause a criticality. However, for Rover-type fuels, as little as 6.7 L of water has been determined from handbook data to be sufficient for a criticality, when combined with the quantity of fuel allowable in a single storage canister. There are no installed sources of water in the handling cave, but residual water is brought into the cave with approved canning station fuels. After each canister is processed in the canning station, any water in the following locations must be removed from the cave or allowed to evaporate before new fuel is brought into the cave:

- On or at the level of the false floor surrounding the tops of the cave walls
- On exposed surfaces in the immediate vicinity where future fuel being handled in the cave could be dropped.

All materials used to absorb the water must also be removed from the cave before the new fuel is brought into the cave. Other areas within the fuel handling cave where water could accumulate do not present a criticality concern because they do not have the potential to mix interstitially with the fuel. However, if accumulated water is discovered elsewhere in the cave, it should also be removed. Exclusion of moderator material in excess of allowed fuel packaging materials, and independent verification by a second certified person that materials to be carried into the cave comply with the moderator limits provide administrative controls against moderator-limit violation.

8.6.1.4.4 Moderator Material Entry into the Cave While Rover Fuel Is Being Handled (With Personnel Entry)—The principal reason for personnel entry into the cave while Rover-type fuel is being handled would be to transfer or repackage fuel, such as would be the case if fuel were spilled from a cardboard tube onto the cave floor. If personnel entry is necessary, a reduced out-of-storage mass limit and the moderator exclusion (except for allowed fuel packaging materials) are applied. Administrative control of the reduced mass limit and the moderator exclusion, plus independent verification of the reduced-mass limit and the moderator exclusion by a second qualified fissile material handler, provide sufficient controls against moderator-limit violation.

In addition, canister inserts containing fuel in excess of the limit allowed during manned entry must be placed in canisters and open canisters and transport containers containing fuel must be closed remotely prior to personnel entry into the cave. For Rover fuel, the manned-entry limit is 8 Kg of U-235 contained in Rover-type fuel. This eight-Kg limit translates to the requirement that a maximum of 66 fuel rods (≤120 g of U-235 per rod) within or outside of cardboard tubes shall be out of storage in the handling cave. In addition, the maximum number of filled Rover fuel tubes allowed out of storage in the handling cave is limited to 15. One Rover fuel canister may be open, and one fuel-filled canister insert containing up to 15 Rover fuel tubes may be out of the canister while personnel are in the cave to remove one tube at a time from the canister insert to Rover fuel transfer devices in the transfer car. This does not degrade the moderator-restricting requirements for Rover fuel in the cave.[52] Any moderator material inadvertently brought into the cave cannot be readily combined with fuel in the unsafe geometry of a fuel container. Liquids inadvertently brought into or sprayed into the cave would be unlikely to combine with fuel material on the cave floor in an unsafe geometry. The cave-well drain valves are required to be locked open when fuel is present in the cave.

8.6.1.4.5 Water Entry into a Canister Containing Rover-Type Fuel in the Storage Area—Entry of a sufficient quantity of water into one fuel canister in the fuel storage area array could cause a criticality if the canister contained Rover-type fuel or Rover UBM (if at least a 56-in. depth of water entered the Rover UBM canister) (see Table 8-3). The roof of the storage area is a 3-ft-thick concrete slab, sloped to drain to its outer edges, covered with an elastomeric sealing membrane, and is designed to prevent water intrusion. For the roof to leak significantly, a seismic event in excess of the DBE would have to occur, causing a significant crack in the roof. Snowmelt or rainfall would have to either be simultaneous with the earthquake or occur before the completion of corrective action (sealing the crack, tarp, etc.). Additionally, the leak would have to continue long enough and provide sufficient water volume to get more than 19.7 L of water into a single canister. Even if water leaked through the storage area roof, the probability of water leaking into or within 2 ft of one of the 19 canisters containing Rover-type fuel among the 636 canisters in the storage rack is less than E-1.

A canister could not be transferred to its storage rack position without a lid, because the canisters are lifted by a bail in the center of the top of the lid. The presence of a canister lid, though not an effective seal, would reduce potential water entry by causing splashing. At least 19.7 L of water would have to enter the canister to reach the bottom of the fuel. Such a criticality is extremely unlikely to occur because of the unlikeliness of the occurrence of a seismic event that would exceed the DBE, coupled with (1) the requisite rainfall or snowmelt, (2) the small probability of a leak occurring above the canisters containing Rover fuel, and (3) the presence of the lids.

8.6.1.4.6 Water Entry into Multiple Canisters Containing Non-Rover Fuel in the Storage Area Array—Fuels processed in the Fuel Canning Station and the other non-Rover-type fuels are less reactive than Rover-type fuels, and full water flooding of a single canister of any of these fuels would not result in a criticality. The same contingencies that make a criticality extremely unlikely in the Rover fuel scenario are applicable in this scenario. Additionally, full flooding (as opposed to partial flooding with Rover-type fuels) of numerous canisters of any other fuel would be necessary for a criticality to occur. Therefore, this scenario is even less likely to result in a criticality than the previous one.

8.6.1.4.7 Water Spilled into a Canister in the Storage Area—If a personnel entry into the handling cave were required, it might be necessary to remove a canister, prior to drying, from the canning station, place it into the shuttle bin and move the shuttle bin to the storage area side of the shield wall. Such a canister could potentially contain significant amounts of water. If a canister were placed in the shuttle bin and moved to the storage area side of the shield wall for this purpose, removal of such a canister from the shuttle bin is not allowed while the bin is on the storage area side of the wall. Storage of canisters from the canning station in the storage area rack is prohibited unless the drying operation is completed. Independent verification by a second certified fissile material handler is required before placing a canister into the storage rack. The second person, therefore, would ensure that an undried canister would not be removed from the shuttle bin.

8.6.1.4.8 Excessive Fuel in the Storage Area Canisters—The arrays of fuel canisters for all graphite fuels in the storage area except Rover-type fuels were evaluated with the canisters loaded to their physical capacity. Fuels from the canning station and Rover UBM are placed in buckets that physically limit the number of fuel elements or Rover UBM cans per bucket. The buckets are in turn placed in the storage canisters that physically limit the number of buckets per canister. Canning station fuels and Rover UBM are usually not handled individually in the IFSF, but are transferred in loaded buckets. The buckets are then loaded directly into the canister while the canister is in the canning station or in a cave well. Inside the handling cave, the Rover UBM buckets are handled in a manner similar to the canning station fuels. Therefore, this type of criticality is possible only for Rover fuel or Tory IIC fuel canisters. The allowed loadings for Rover-type fuels in cardboard tubes and canister inserts, along with their basis calculations, are presented in Addendum A to this SAR. The k_{eff} values for Rover-type fuel in metal tubes are similar to or slightly less than those for the same numbers and configurations of cardboard fuel tubes.[52] The loading limits for Rover fuel and Tory IIC tubes into canister inserts are near the physical limit. Overloading several of these canisters and placing them in the storage area would be required for a criticality to occur. Failures of compliance with canister loading limits by a certified fissile material handler and of independent verification of compliance by a second certified person are two controls against this postulated criticality. Many of the fuel elements or fuel storage buckets are physically too large for overloading to occur.

8.6.1.4.9 Water Flooding of the Lower Levels of the IFSF—A criticality would not result from flooding of the lower levels of the IFSF. Seismic analyses of the CPP-603 FSB have shown that an DBE may cause the basin parapet to leak but would not result in massive failure that could flood the IFSF. Dropping a heavy cask onto the edge of the basin parapet wall might cause a significant leak. Water from outside the facility could seep into the facility through cracks caused by an DBE or some other possible leak path.

If a leak in the basin wall occurred, water could flow east and west into the south truck bay and north into the north truck bay. Some would flow out the facility doors, and some would fill the truck ramp south of the IFSF wall. Some of the remaining water would fill the transfer car pit. Water could become backed up through the cave-well drains, the shuttle-bin drain, and storage-area drains. Sufficient water is available in the FSB to cover the IFSF lower levels only to approximately the - 2-ft-9-in. level. Because the storage area floor is at - 3 ft and the fuel storage canisters sit 3 in. above the floor, the canister tops are well above a level that water could reach. Therefore, water could not overflow into a storage canister in the storage area, the handling cave, or the shuttle bin.

If the facility walls or roof were cracked by the DBE, inleakage could occur if sufficient water were available at the location of crack. The four light-access doors on the north wall of the storage area have gasketed closures. If a gasket seal were faulty, some, probably very small, inleakage could occur. If inleakage were to occur, the facility floor drains would remove at least some of the water. However, the inflow rate could exceed the outflow, allowing water to back up. Because the water level could never reach the top of the fuel storage canisters, water would not enter the canisters through the tops, but could enter any canister without a watertight bottom.

The canisters are constructed of 18-in. Schedule 10 steel pipe with 1/2-in.-thick steel plate bottoms welded in place, and are designed to be watertight. Leak-tightness of the canister bottoms has been tested on a sampling basis. Water entry to a sufficient depth into a single, isolated canister containing Rover-type fuel could result in criticality, but water entry into a canister containing any other type of fuel could not result in a criticality. In the storage area and the fuel handling cave, water rising above the floor among the canisters would actually cause a reduction in the array reactivity by providing neutron isolation between canisters, provided water did not leak into any of the Rover-type fuel canisters or Rover UBM cans inside the fuel storage canisters. The latter would require the water to reach about 56 in. above the bottom of the Rover UBM canister (see Table 8-1).

8.6.1.4.10 Dropping of a Loaded Canister or Bucket onto a Rack Containing Fuel in the Fuel Handling Cave or Storage Area—Canisters and buckets are handled using engineered equipment that is load-tested and maintained in the INTEC preventative maintenance (PM) program. Qualified fissile material handlers, operating with approved procedures, ensure that no more than one FHU is out of approved storage at one time. Any one loaded canister or bucket on top of a loaded rack position is critically safe. If the canister bottom or lid were to come open and the fuel were to spill out on top of the rack, the contents of a spilled canister of Rover-type fuel, Rover UBM cans, or TRIGA-Al, the most reactive fissile materials when dry, on top of the loaded storage rack, would be critically safe. A dropped canister could not penetrate through the top of the storage rack because of the presence of structural material surrounding all storage positions. A canister could fall into an open storage position, but this would result in a normal storage condition. The most reactive fuels, Rover fuel and TRIGA-Al, have been evaluated as homogeneous hemispheres, with concrete reflection on the bottom side, among the fuel canisters. If the hemisphere were on top of the rack, the concrete reflector would not be present and the distance from the fuel array would be greater. Therefore, if the fuel configuration were lost for these fuels, they would still be safe. Analyses of Rover UBM conservatively assume it to be potentially as reactive as these two fuels. Rover UBM cans would survive a rack drop, and one intact Rover UBM canister or 12 Rover UBM cans spilled respectively onto or into the center of a storage rack sub-array of 59 Rover fuel canisters are shown in the CSE[70] to remain critically safe.

For the floor well racks in the IFSF fuel handling cave, a drop of a loaded canister (up to 2,000 lb) could lead to structural failure of some rack members (see Subsection 8.5.3). Under such conditions, the spacing of floor wells could be reduced from design values. If two or more canisters were in the floor well rack at the time, they could move close together and be surrounded by the spilled contents of the dropped canister. This would create a condition which is unanalyzed from a criticality safety view. To avoid this unanalyzed condition, the IFSF fuel handling cave, outside of the cask transfer car, is limited to two fully loaded canisters or their approved contents.[75] In this way, if one of the two allowed canisters were to drop, its contents could only spill around one other canister. This reduces this condition to one that is enveloped by the storage area scenarios (see also Subsection 8.6.1.4.11). Spacing considerations are then irrelevant, because only one stored and one dropped canisters are involved. Alternatively, a CSE for a specific fuel type could be performed showing that loss of floor well spacing is not a criticality concern.

Multiple failures would have to occur before a criticality would be possible. If one drop accident occurred, the dropped unit would be out of storage, and removing a second unit from storage is prohibited. Operations would not continue until recovery from the first drop was completed.

8.6.1.4.11 Dropping of a Loaded Canister and Fuel Spilled Out into a Cave Well— A criticality accident can be postulated in which a loaded fuel canister could drop, the canister bottom or lid could fail, and the fuel could spill out. The fuel could then fall into an open storage rack position or cave well. This is similar to the previous scenario except in this scenario the fuel spills into the bottom of a storage position, among the array of fuel in storage. The contingencies against this occurring are the same as in the previous scenario. An evaluation has shown that the contents of three Rover fuel canisters, in a hemisphere on the concrete floor, would have a k_{eff} of less than 0.95. This case represents conservatively this postulated accident in which the dropped canister contained Rover-type fuel and fell among other Rover fuel-containing canisters. The hemisphere of the contents of three Rover fuel canisters represents the dropped canister and the closest two canisters in the rack, conservatively formed into a single hemisphere. The contents of a TRIGA-Al can were likewise modeled in a hemisphere placed on the floor next to two intact TRIGA-Al canisters in the array. These two fuels are the most reactive fuels approved for storage in the IFSF and envelop all other fuels that could be in the facility. Analyses of Rover UBM cans show that they would survive this drop, so that for Rover UBM, this case is enveloped by the rack drop case in the previous subsection. Because these arrays are critically safe, an additional similar accident would be required before a criticality would be possible. This would require many additional contingency failures; therefore, this scenario is extremely unlikely to occur.

As discussed above, the drop of a fully loaded canister onto the fuel handling cave floor well rack could lead to the loss of spacing of the floor wells. For this reason, the fuel handling cave outside of the cask transfer car is limited to two fuel-loaded canisters or their approved contents. This reduces the criticality concern for this scenario to the interaction of one canister with the spilled contents of a second canister. This interaction is enveloped by the criticality calculations performed for the storage rack with multiple canisters. Again, a fuel-specific CSE could eliminate floor well spacing concerns for certain fuel types.

8.6.1.4.12 Spilling of an Allowed Fuel Type into a Cave Well or the Canning Station Containing Fuel—The presence of multiple units of fuel in storage in the handling cave is allowed provided that only one type of fuel (or an allowed combination of fuels) is present. Note that this is still subject to the two canister restriction discussed in 8.6.1.4.10 and 8.6.1.4.11 above. Two canisters, in approved storage locations, containing fuel of the same type fuel (or an allowable combination) may be open to allow transfers between canisters, if necessary. A canister being transferred to an approved storage location could be dropped, or a lesser FHU such as a bucket or fuel element could be dropped. If one of these units were dropped, fuel could spill out. The occurrence of a criticality can be postulated if the fuel spilled out and entered an open or closed storage location. Entry into a closed location might be possible if the dropped FHU caused sufficient damage to the lid or cover of the fuel in storage.

The contingencies against the occurrence of this postulated criticality are the unlikely failure of engineered lifting equipment or operator error in properly using the equipment, and the fact that a sufficient amount of fuel from the spill to cause a criticality could not enter the canister or storage position. An administrative control prohibits more than one fuel-type in the handling cave at a time except fuels that are specifically authorized for combination in the canning station. Only fuels of the same type (or an allowable combination) are permitted. Fuels in allowable storage configurations have been analyzed for overbatching and shown to be safe for any credible overbatching, given physical size restraints of canisters, inserts, buckets, Rover UBM cans, and fuel elements. The two larger diameter cave wells will be filled with the canning station and covered with the vacuum lid set-down table, respectively, when Rover UBM is in the cave. Thus, Rover UBM cans are also precluded from falling into any annular space between a canister and a cave well. Even though most Rover UBM will be received in a rubblized condition and the aluminum Rover UBM bucket would fail in some drops, all Rover UBM is placed in leak-resistant cans before receipt at the IFSF. The cans have been shown by analysis to survive a drop of as much as 24.3 ft.[32,33] Twelve intact dropped Rover UBM cans (the maximum number in the cave at one time) will not form a critical array in a dry environment.[70] Therefore, the occurrence of a criticality in this scenario is extremely unlikely.

8.6.1.4.13 Spilling of an Unallowed Fuel Type into a Cave Well or the Canning Station Containing Other Fuels—An administrative control prohibits more than one fuel type in the fuel handling cave at a time, except for fuels that are specifically authorized for combination in the canning station. For a postulated criticality accident to occur in this scenario, a violation of this control would first have to occur, introducing a disallowed FHU into the cave. Then, a failure of engineered lifting equipment or operator error in the use of the equipment would have to cause the FHU to be dropped. If the dropped FHU were to fall into the canning station or a cave well containing another fuel type, an unanalyzed combination would result and a criticality might be possible.

The presence of other fuels in the fuel handling cave is prohibited during Fuel Canning Station operations, except that an allowed fuel may be transferred to the canning station while other fuel is already in the canning station. For fuels other than canning station fuels, canisters or storage positions containing fuels are required to be closed during transfers within the handling cave, except that two storage positions (one position from which the FHU is being transferred and one position to which the FHU is being transferred) may be open. The canning station cover must also be in place when any other fuels, except those being transferred to the canning station are being handled.

These restrictions prevent the formation of unanalyzed mixed arrays of fuels and are enforced by administrative controls requiring independent verification by two qualified fissile material handlers. Accidental dropping of fuels is unlikely because of specially engineered lifting equipment and operation by qualified operators using approved procedures for fuel handling operations. Therefore, the occurrence of a criticality in this scenario is extremely unlikely.

8.6.1.4.14 Two or More Rover UBM Cans Rolling into the IFSF Sump—The sump is under the PCS in the transfer car pit. If the sump were filled with water, a criticality could occur if two or more Rover UBM cans entered the sump. The sump is about 5 ft deep with a rectangular opening about 2 ft by 3 ft. Rover cans are approximately 4.5 in. OD and 56 in. long, so several cans could be wholly or partially submerged in a water-filled sump. The only time that more than one can could conceivably roll to the sump would be in the event that inside the handling cave one loaded Rover UBM bucket inadvertently dropped onto the other as it was being moved out of the transfer car. If the total force of the drop were sufficient to punch through the transfer car insert, then several cans could come out of the buckets. This would enable some cans to roll toward the sump. Mitigating against this event are: (1) the Rover UBM transfer car insert adapter has been designed to withstand the force that could be generated by this drop, (2) the bucket path between transfer car and canister in the handling cave is precluded from passing over another loaded bucket, (3) a sump pump is automatically activated when there is water in the sump, and (4) an engineered method is in place to preclude the possibility of Rover UBM cans rolling into the sump.

8.6.1.4.15 Fuel Canisters Are Moved/Rearranged into a Critical Storage Arrangement—Previously, any arrangement of fuel storage canisters approved for storage for the IFSF was critically safe in the storage rack, so that the specific position of individual fuel storage canisters was not a safety requirement. However, the addition of an increasing quantity and variety of fuels, including Rover UBM, potentially increases the total array reactivity sufficiently for restrictions to be required as to which positions specific loaded fuel canisters may occupy relative to other canisters containing fissile material. A CSE[76] has been done which extensively explores this issue. The referenced CSE has analyzed many alternate canister positions for various fuels and configurations. The majority of these other analyzed storage array cases are also critically safe. This CSE concludes that at least 20 to 25 of the most reactive fuel-loaded storage canisters must be in storage area positions different from the mapped configuration before criticality safety of the storage array could be compromised. Even then, these 20 to 25 canisters would have to be in especially reactive storage positions relative to certain other fuels. Also see Section 7.2.

To prevent this type of criticality, adherence to the fuel storage array requirements delineated in TS 4.12A1 is mandatory. The requirements include specification of allowed fuel configuration in canisters and of allowed array location for canisters containing each allowed fuel and configuration combination. It is prohibited to change the fuel storage area array without approval of the criticality safety organization and DOE. The criticality safety organization will determine if the change or addition has already been analyzed (see above). These requirements ensure that fuel is stored only in those storage array configurations which have been evaluated as critically safe.

8.6.1.4.16 Excessive Rover UBM Cans Out of Approved Storage Containers in Cask Receiving Area—In a dry environment at least 24 cans of Rover UBM must be out of storage and moved into a close-packed arrangement before a criticality could be achieved. Rover UBM cans in the cask receiving area are normally in closed 6M drums. The drum dimensions inherently provide critically safe geometry for Rover UBM. Controls are in place which preclude more than one Rover UBM can from being out of either a closed 6M drum or one of the Rover UBM buckets in transfer car. Controls are also in place which (1) require the 6M drum array to conform to default DOT transport index requirements and/or to exceptions specifically analyzed in a CSE,[77] and (2) prevent any other non-Rover UBM fuel or fissile material in excess of 350 g from being less than 20 feet of air (or equivalent neutron attenuation) from any Rover UBM.

In a non-dry environment, at least two internally and externally flooded and close-packed Rover UBM cans are required for criticality. This could happen if the cans were dropped into the truck ramp while the ramp was flooded and were left there for an extended period of time so that the gasket-closed cans might be breached. The same controls as above preclude more than one can being out of a closed drum or one of the buckets in the transfer car. Additionally, a procedural requirement is in place to remove any visible water from the truck ramp before Rover UBM cans are moved from a drum to the PCS. One can is critically safe even if flooded.

8.6.1.4.17 Excessive Rover UBM Cans Out of Approved Storage Containers in Fuel Handling Cave—Controls are in place which prevent more than one Fuel Handling Unit (FHU) from being out of approved storage at one time. The largest number of cans in a Rover UBM FHU is 12 cans, which are configured in 2 buckets stacked in a storage canister. In a dry environment, at least 24 cans of Rover UBM must be out of storage and moved into a close-packed arrangement before a criticality could be achieved.

Controls are also in place that require any visible water to be removed from the cave or evaporated before further fuel is brought into the cave. The likelihood is extremely remote that sufficient water could accumulate anywhere in the cave so that three or more closely packed Rover UBM cans could be submersed in it for the extended period of time needed for the cans to become internally flooded. This flooded cans scenario is not credible.

8.6.1.4.18 Water Flooding of a Canister Containing Rover Uranium Bearing Material in the Storage Area—The only credible way for sufficient water to enter the storage area to initiate this scenario is by roof failure caused by a seismic event. There would have to be sufficient precipitation or snow melt available to enter through the failed roof at the time of failure or before temporary repairs could be made. However, Rover UBM storage canisters have leak-proof bottom welds and a water-shedding lid design, so that water from a roof leak will not enter into the canister. Furthermore, the water would have to enter some of the Rover UBM cans inside the canister before a criticality would be possible. A criticality will not occur in a flooded storage canister containing Rover UBM cans which remain dry inside. Finally, the Rover UBM cans themselves are closed with torqued gasketed lids, which are considered leak-resistant. (In fact, tests have indicated that the lids are in fact leak-proof, but they cannot be qualified as such because of the destructive nature of a qualifying test.) This criticality scenario is not considered credible.

8.6.1.4.19 ***Water Flooding of Rover Parka Fuel in the Transfer Car–No Transfer Device Used***—Cardboard tubes of Rover Parka fuel from one storage canister insert will be removed from the cave in the Rover UBM insert adapter in the transfer car. The 15 cardboard fuel tubes in one canister insert are critically safe without any configuration control if they remain dry. When the transfer car is moved into the PCS, there is a small, although extremely unlikely, chance that water could abruptly enter the Rover UBM insert adapter and soak the cardboard tubes. Therefore, whenever more than 4 Rover fuel tubes (based on a maximum of 600[a] g U-235 per tube, equivalent to five 120–g rods per tube) are moved to the PCS in the transfer car, it is required that they be in Rover fuel tube transfer devices (TD-GSF-928-1 or -2). Because safe geometry and spacing are maintained within the Rover UBM insert adapter (ADP-GSF-3) by the transfer devices, up to eight Rover fuel tubes (the maximum number of Rover fuel tubes that can fit in a transfer device) in each transfer device are critically safe even when fully flooded.

8.6.1.4.20 Fuel Loaded Cask Drops from Cask Transfer Car and Fuel Spills Out onto Pit Floor—A criticality accident can be postulated in which a fuel-loaded cask could drop into the cask transfer car pit. The accident could be initiated by the drop of a heavy load (such as a cask or fuel storage canister) onto the cask while the cask is supported in the cask transfer car. The fuel could then spill in the cask transfer car pit. These accidents are analyzed, and controls are derived as necessary in the cask or fuel handling operation-specific safety documents. A summary of the qualified loads allowed in the IFSF transfer car, as derived in these various safety analyses, is presented in Table 8-1 above.

8.6.1.5 Criticality Accident Consequences. The previous physical and administrative controls minimize the probability of an occurrence of a criticality in the IFSF. However, because a criticality could have severe radiological consequences to operating personnel and collocated workers, the consequences of hypothetical criticality accidents were analyzed. Because the consequences of a criticality are the worst that can be expected from any accident postulated for the facility, a criticality is determined to be the maximum postulated accident (MPA). Any other type of accident should result in lower radiological consequences than those calculated for an MPA.

Two criticalities involving different fuel types are assumed to occur in the fuel handling cave. Other criticality accidents are assumed to occur in unshielded areas, namely the cask receiving area and the transfer car pit.

8.6.1.5.1 Fuel Handling Cave Criticality—The MPA inside the IFSF is a criticality accident that occurs in the fuel handling cave. It is assumed that administrative and other controls are violated and that a critical array of Rover fuel is accumulated.[78]

Fission products produced by the MPA are assumed to be released to the environment via the existing exhaust pathway. This pathway routes the fission products through a roughing filter at the exit of the fuel handling cave (assumed to be ineffective in the MPA), then through one of two filter trains

---

a. Note, however, that even when a maximum of 480 g U-235 per fuel tube is assumed, contents rubblized, and flooded with no configuration control k_{eff}<0.95 can only be assured with four or fewer tubes.

containing prefilters and HEPA filters, and finally up the 65-ft-tall stack. Calculations were performed for both mitigated (with filters in place) and unmitigated (without filters) conditions. Atmospheric transport carries the fission products to the downwind receptors. The most conservative atmospheric conditions for each downwind location were assumed.

The assumptions used in modeling the MPA are listed below:

1. Source Term

   a. The maximum case fission product activity occurs in Rover fuel with a 10-yr decay time.

   b. One $\times 10^{18}$ fissions occur in irradiated Rover fuel.

   c. Twenty-five kg of U-235 was involved in the criticality. The amount of the fuel involved in releasing fission products is 10%. DOE airborne release fractions (ARF) of radionuclides are used.[79]

2. Facility Release Conditions

   a. Radioactivity is first released to the fuel handling cave, then into the facility exhaust system. Exponential release with a removal half time of 3.5 minutes is assumed, and the additional time of 2 seconds to reach the HEPA filters and 1.8 seconds to reach the stack exhaust are added.

   b. No credit is taken for roughing filters or prefilters.

   c. All of the available noble gases and halogens in the fuel handling cave are exhausted through the stack.

   d. HEPA filters remove 99.9% of particulate, and calculations are performed with and without the filters.

   e. Final exhaust is through a 19.8-m (65-ft) stack.

3. Meteorological Release Conditions

   a. Conditions are varied to give the most conservative (highest) exposures at each of the three evaluated locations.

   b. Hilsmeier-Gifford diffusion parameters are used.

   c. Receptors are located at distances of 100 m, 644 m, and 13,500 m (nearest site boundary) downwind from the stack.

4. Exposure Conditions

   a. The RSAC-5 default lung clearance model is used.

   b. A 3.33 E-4 m^3/second breathing rate is used.

   c. A 1-μm activity median aerodynamic diameter particle size is used.

Downwind doses were calculated using the RSAC-5 computer code. The code generates the fission-product inventory from the criticality incident, fractionates the inventory according to the assumed airborne release fractions, models the radionuclide transport to the receptor, accounts for the HEPA-filter efficiency, and models the inhalation and energy disposition of nuclides in the receptor. The results of the RSAC-5 calculation are shown in Table 8-5.

Table 8-5. Downwind doses from Rover criticality in the CPP-603 Fuel Handling Cave (rem)[78]

		Inhalation 50-Year Committed Dose Equivalent (rem)				
Downwind Distance (m)	HEPA Filter	Inhalation	Ingestion	Ground Surface	Cloud Gamma	Total EDE
100	yes	3.3E-05	-	2.1E-05	5.9E-03	5.9E-03
100	no	4.5E-05	-	2.3E-05	6.4E-03	6.4E-03
644	yes	6.9E-05	-	3.8E-05	1.4E-03	1.5E-03
644	no	9.3E-05	-	4.3E-05	1.5E-03	1.6E-03
13,500	yes	2.2E-06	4.7E-06	1.5E-06	9.7E-06	1.8E-05
13,500	no	2.8E-06	7.1E-06	1.7E-06	1.1E-05	2.2E-05

The total unmitigated EDE for the MPA to a worker at 100 m away from the IFSF is 6.4E-03 rem, to a collocated worker at 644 m away from the IFSF is 1.6E-03 rem, and to a member of the public at the nearest INEEL boundary (13,500 m) is 2.2E-05 rem. The doses to on-site workers are within the annual occupational limit of 5 rem.[37] The doses to a collocated worker and to an individual at the INEEL site boundary are well below the INTEC evaluation guidelines of 25 rem and 5 rem, respectively, for unlikely events.

In addition, the risk of an individual at the INEEL boundary receiving the doses listed in Table 8-5 is further reduced by the remote location of the INEEL in relation to population centers and the fact that the highways and roads on the INEEL are patrolled by security forces, enabling traffic to be interrupted during emergency situations.

A separate dose calculation, using ATR fuel processed in the canning station for the source-term derivation and similar ARF, facility, and atmospheric assumptions, was performed.[80] This was done to evaluate potential consequences of an assumed, unlikely, nonmechanistic criticality involving the most highly irradiated fuel processed in the canning station. The calculated dose consequences were very similar to those for the postulated Rover fuel criticality, except for the site boundary unmitigated case, for which the calculated dose was a factor of 20 times greater. This off-site dose value, 4.6E-4 rem, is still well within the INEEL evaluation guideline of 0.5 rem. The reason for the similarity of consequences is that the dose is dominated by the criticality itself, and is not greatly influenced by existing fission products in the fuel. The exception, the unmitigated site boundary exposure, is caused by long-lived solid fission products that are not removed by the HEPA filters. The products are significant in the very low site-boundary case.

8.6.1.5.2 Cask Receiving Area Criticality—This accident is discussed in Addendum A to this SAR.

Radiological dose calculations were performed for an unshielded criticality in the Denitrator (CPP-602) basement area.[81] Very similar consequences could be expected from a criticality in the IFSF cask receiving area.

Gamma and neutron radiation released in the area would cause fatalities within a 15-to-20-ft distance of the excursion, and significant, potentially lethal, radiation doses to individuals in adjacent unshielded areas. Internal doses from inhalation or ingestion are insignificant in relation to the doses received from the prompt doses from gamma and neutron radiation. The off-site radiation doses would be insignificant.

8.6.1.5.3 Rover UBM Criticality in the Transfer Car Pit Sump—This accident is described as a second MPA, since the calculated dose releases are actually higher than for the preceding MPA described in Subsection 8.6.1.5.1, although still well within the guidelines stated there. The heterogeneity and lack of good advance characterization of Rover UBM caused multiple layers of conservatism to be used in the calculation assumptions. Actual dose releases would be expected to be significantly lower than those calculated and comparable to those of the MPA in Subsection 8.6.1.5.1.

Many of the dose release calculational assumptions for this MPA are the same as for the preceding one in Subsection 8.6.1.5.1. Major assumptions are itemized below.[82]

1. Source Term

   a. The maximum case fission product activity occurs in Rover UBM with a 24-yr decay time.

   b. One x 10^{19} fissions occur in irradiated Rover UBM.

   c. The maximum amount of fissile material in 12 Rover UBM cans (43.1 kg U-235) was involved in the criticality.[83] Twelve, is the number of cans in two Rover UBM buckets, or one transfer car load. DOE ARF of radionuclides are used.[79]

   d. The existing radionuclide inventory in the Rover UBM was calculated using the ORIGEN2 computer code for 93.07% enriched uranium. This enrichment value was obtained from lab samples of Rover UBM.

   e. The 12 cans of Rover UBM are assumed to rupture in the criticality accident, and the contents are assumed to disperse into approximately 850 L of water in the sump.

   f. Iodines are assumed to evolve by decay from the reaction for approximately 20 min following the criticality.

2. Facility Release Conditions

   a. Radioactivity is first released from the transfer car pit to the fuel handling cave, then into the facility exhaust system. The PCS is assumed to be closed, so that none is released to the cask transfer area. Exponential release to the IFSF stack exhaust is assumed with a removal half time of 4.2 min.

   b. No credit is taken for roughing filters or prefilters.

   c. All of the available noble gases and 25% of the radioiodines in the sump, and 0.05% of the particulate activity in 100 L of solution are released to the transfer car pit. The scrubbing action of high humidity that would be generated in the pit is assumed to reduce the radioiodines by an additional factor of two.

d. HEPA filters remove 99.9% of particulate. Calculations are performed with and without the filters.

e. Final exhaust is through a 19.8-m (65-ft) stack.

3. Meteorological Release Conditions

a. Conditions are varied to give the most conservative (highest) exposures at each of the three evaluated locations.

b. Because the release is assumed over a period of more than 15 min, Markee diffusion parameters are used.

c. Receptors are located 100 m, 644 m, and 13,500 m (nearest site boundary) downwind from the stack.

4. Exposure Conditions

a. The RSAC-5 default lung clearance model is used.

b. A 3.33 E-4 m^3/second breathing rate is used.

c. A 1-µm activity median aerodynamic diameter particle size is used.

See References 82 and 83 for more discussion of the postulated dose releases.

Some of the differences between this criticality accident and others postulated for the IFSF arise from the fact that the Rover UBM is handled as individual cans, or as cans in open buckets, both outside and inside of the handling cave. Also, the nature of the Rover UBM, although derived from Rover fuel, is different due to additional, nonfuel material, partial processing and general heterogeneity. Additionally, these factors combined with uncertain characterization information to cause very conservative assumptions to have been made regarding the Rover UBM. The calculated dose releases for this MPA are summarized in Table 8-6.

Table 8-6. Downwind doses from Rover UBM Criticality in the CPP-603 Transfer Car Sump[82]

	Pathway Contribution to the Effective Dose Equivalent (rem)					
Downwind Distance (m)	HEPA Filter	Inhalation	Ingestion	Ground Surface	Cloud Gamma	Total EDE
100	yes	4.4E-04	-	1.6E-04	4.3E-01	4E-01
100	no	5.8E-04	-	1.7E-04	4.6E-01	5E-01
644	yes	8.1E-03	-	2.6E-03	1.2E-01	1E-01
644	no	1.1E-02	-	2.8E-03	1.3E-01	1E-01
13,500	yes	1.0E-04	4.2E-04	9.5E-05	1.9E-04	8E-04
13,500	no	1.3E-03	4.2E-04	1.1E-04	1.1E-04	9E-04

8.6.2 Loss of Coolant Flow

A loss of coolant flow can result from (1) a failure of the cooling air supply and exhaust blowers, (2) a loss of both the normal and backup power systems, and (3) a complete blockage of either or both the inlet and outlet ducting or the inlet and outlet filters. However, for serious consequences, a loss of coolant flow must be both complete and long-term. Anything less would provide ample time in which to take corrective action before the graphite fuel centerline temperature upper limit of 1,100°F (866 K), or an aluminum fuel temperature upper limit of 482°F (523 K), would be exceeded. Wigner energy in the graphite lattice during neutron irradiation was annealed out during normal operation of the reactors and thus does not contribute to the heatup rate of the graphite fuels upon loss of cooling air in the IFSF. Long-term coolant flow losses are discussed in the following paragraphs.

8.6.2.1 Long-Term Coolant Flow Loss (>22 days). The consequences resulting from a total and extended (>22 days) loss of coolant are postulated for both fuel and the IFSF. The analysis shows that a lengthy loss of coolant could have a potentially more serious effect on the facility structure than upon the fuel. In developing the analysis and the resultant consequences, the following conditions were assumed:

1. The normal fuel storage area cooling airflow through the storage rack is 12,000 ft^3/min, and 2,000 ft^3/min above the rack.

2. All cooling system blowers, supply and exhaust, become inoperable.

3. Corrective action cannot be completed within 22 days.

4. The facility is filled with fuel.

5. The fuel is stored in steel canisters having lids.

8.6.2.2 Fuel Effects. The maximum decay heat rate of the stored fuel in the IFSF is 767,671 Btu/h.[24] If a loss of coolant were to occur, the temperature would slowly rise. With only the adiabatic heating of the thermal mass of the facility, the stored fuel, the canisters, and the storage rack, the facility temperature would not increase to 400°F (477 K) in less than 37 days.[26] Assuming natural convection and heat loss through the facility walls and roof only, the centerline temperature of the hottest Fort St. Vrain element would reach a steady state value of 828°F (715 K) at a time greatly exceeding 30 days.

The irradiated graphite fuel is stored in 0.25-in.-thick steel canisters having lids. Graphite begins to slowly oxidize in free air at about 1,000°F (811 K), but only a limited air supply is available to the fuel inside the canister. The canisters have been shown to retain their integrity at 1,300°F (977 K).[84] The graphite fuel matrix has been shown to maintain fission product containment to temperatures in excess of 2,850°F (1,839 K).[31] Thus, a loss of cooling would not have a significant effect on stored graphite fuel and would cause no significant release of fission products.

The graphite oxidation results discussed above have been substantiated in tests performed at the INTEC.[30] During these tests, reactor-grade graphite samples were heated for 31 hr at temperatures ranging from 800°F (700 K) to 1,400°F (1,033 K). The samples were tested under two test conditions: one with the samples open to the atmosphere and the other with the samples contained in a sealed metal canister representative of a storage canister. The results of the tests are shown in Table 8-7. When the graphite is contained, the oxidation of graphite is negligible. However, if air is available, the oxidation increases, particularly around 1,300°F (977 K). No runaway condition of combustion, however, is possible at any temperature.[31]

Based on the above, a loss of coolant would have no detrimental effect upon the stored fuel as long as the fuel is contained. Before fuel temperatures could reach a level that would be harmful to the storage canisters (approximately 1,300°F [977 K]), at least partial coolant flow could be restored to the storage facility.

Table 8-7. Effect of temperature upon graphite oxidation.

Original Sample Weight (g)	Temperature (°F)	Rate of Graphite Weight Loss (g/hr) Open Container	Rate of Graphite Weight Loss (g/hr) Closed Container
68	800	0.00	--
68	1,100	0.05	0.008
70	1,200	0.51	--
70	1,300	1.90	--
68	1,400	2.42	0.007

The temperature rise of a canister containing ATR fuel elements from the Fuel Canning Station has been evaluated.[27] ATR fuel has the highest decay heat generation of any of the fuels from the canning station. Data from the temperature evaluation has been used to demonstrate that the heat generation and the facility effects determined for Fort St. Vrain fuel envelop those for ATR fuel, and therefore, all canning station fuels.

A canister containing ATR fuel, generating a maximum of 921 Btu/h, would reach an equilibrium temperature of 268°F (404 K) in 100 hr if the canister were in a large room with an ambient air temperature of 70°F (294 K). Given that, if a loss of cooling airflow occurred, the ambient air temperature would rise and the fuel temperature would rise accordingly. If ambient air temperature were 90°F when the cooling flow loss occurred and the temperature increased 0.344°F/h (see Subsection 8.2.1), and if the maximum fuel temperature were 198°F above ambient, then approximately 535 hr (>22 days) would be available before the fuel temperature would reach 482°F (523 K), the temperature at which fuel cladding blistering and slump could begin to occur.

8.6.2.3 Facility Effects. A lengthy loss of coolant in the fuel storage facility could have a potentially serious effect. Sustained high temperatures can weaken concrete and cause cracking and spalling. In addition, high temperatures could damage and destroy internal facility equipment including HEPA filters, shielding windows, the crane, manipulator, crane rails, movable shielding wall, etc. Numerous tests have been performed to determine the effect of temperature upon the properties of concrete. Though the results of the tests are not directly comparable because of the variables involved, all the tests show that the compressive strength of concrete decreases with increasing temperature. The facility temperature would not exceed 300°F (422 K) even if the facility were filled and if all cooling airflow were lost for at least 25 days.[24] The results of the tests performed on concrete show that serious loss of compressive strength does not occur at those temperatures below 300°F (422 K).[85] The report recommends that structural concrete should not be exposed continuously to temperatures above 500° to

600°F; therefore, at least the 22 days of loss of cooling, shown to have a minimal effect on the stored fuel, would also not have a serious effect on the facility. Before temperatures could reach harmful levels, at least partial coolant flow could be restored to the facility.

Regardless of the circumstances causing a loss of coolant, 22 days are available in which corrective action could be taken before temperatures within the facility reach hazardous levels. Corrective action could include almost anything that would provide cooling flow and could range from replacing existing blowers to obtaining and installing a temporary blower powered by a portable gasoline generator. In addition, corrective action need not restore full cooling.

Based on the design of the facility, heat transfer calculations, graphite oxidation tests, and the fuel storage method, the probability of a loss of coolant occurring and causing serious consequences is extremely low. More than three weeks would be available to restore coolant flow in the event of complete loss of cooling for those graphite or canning station fuels that produce maximum decay heat.

8.6.3 Cask Drop Accidents

An accident is postulated in which the Fort St. Vrain cask is dropped while in transit between the truck bed and the cask transfer pit. This accident is extremely unlikely because applicable precautions and controls for routine cask handling, as discussed in PSD Section 4.5, are also specified for the Fort St. Vrain cask. A cask drop analysis shows that for any credible cask drop scenario, the Fort St. Vrain cask would not breach, even if the cask were dropped from a maximum height lift.[86] Drop accidents involving the high-load charger are evaluated in the safety assessment for use of the charger for transferring canning station fuels: Addendum A to PSD Section 4.5. Drop accidents involving the ATR cask are evaluated in the safety assessment for use of the cask for transferring ARMF and CFRMF fuels: Addendum M to PSD Section 4.5.

There is no potential for acute radiation exposure to personnel or a release of radioactive nuclides to the environment from exposed fuel associated with a cask drop. However, if a cask were dropped, significant property damage and injury, including fatality, may result.

8.7 References

1. A. G. Ware, et al., *Seismic and Wind Analysis of the Irradiated Fuel Storage Facility at the Idaho Chemical Processing Plant*, INEL-96/0104, May 1996.

2. S. Bolourchi and L. E. Malik, *Nonlinear Seismic Analysis and Evaluation of the IFSF Fuel Storage Rack*, AEC Job No. 6100, Advanced Engineering Consultants, Inc., June 1996.

3. C. A. Moore letter to R. L. Campbell, "Revised Stress Analysis of the IFSF Fuel storage Rack Canister Assembly, CAM-25-96, June 20, 1996.

4. M. E. Nitzel et al., *Structural Analysis of the Modified Irradiated Fuel Storage Facility at the Idaho Chemical Processing Plant*, INEEL/EXT-97-01027, December 1997.

5. DOE-ID AE, "DOE-ID Architectural Engineering Standards," Sections 0111 and 0112, Rev. 13, September 1992.

6. DOE-STD-1020-94, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," U.S. Department of Energy, April 1994.

7. G. K. Miller, *Low Temperature Operation of the IFSF Storage Rack*, INEEL/EXT-98-00880, August 1998.

8. A. B. Christensen, R. G. Rahl letter to M. A. Stubblefield, "Low Temperature Materials Concerns at the CPP-603 IFSF," ABC-13-98, RGR-24-98, September 30, 1998.

9. K. B. Woods letter to H. A. Worle, "IFSF Seismic Canister Evaluation," KBW-03-96, July 1, 1996.

10. M. J. Russell, D. T. Clark, *Seismic Analysis of the IFSF Cave Racks*, INEEL Calculation No. 2183, Rev. 2, January 21, 1999.

11. EDF-1871, "Independent Review of Seismic Qualification of Selected Equipment Mounted on the IFSF Transfer Car," Rev. 0, S. R. Jensen, March 7, 2001.

12. EDF-1816, "Seismic Analysis of the IFSF Transfer Car Insert and Saddle for the GNS-16 Cask," Rev. 1, M. J. Russell, April 19, 2001.

13. EDF-3501, "Structural Analysis of HFEF-6 Cask Support in IFSF Transfer Car," Rev. 0, P. E. Murray, N. B. Smith, March 5, 2003.

14. EDF-3034, "TN-FSV Transfer Car Insert Adaptor," Rev. 0, W. E. Landon III, December 2001.

15. EDF-3028, "Analysis of Peach Bottom Cask CPP-603 Lift Adapters and IFSF Transfer Car Inserts," Rev. 0, W. E. Landon III, February 19, 2002.

16. EDF-2951, "Seismic Qualification of IFSF Transfer Car Equipment Under Peach Bottom Fuel Transfer Container (TD-SF-966) Loads," Rev. 0, M. J. Russell, October 2001.

17. EDF-3018, "PLT-GSF-908 Insert Ring Used With NAC-LWT Cask," Rev. 1, N. B. Smith, September 19, 2001.

18. EDF-3167, "Design Analysis of the Japanese Cask Insert INRT-GSF-28," Rev. 1, C. D. Thompson, April 2003.

19. K. N. Koslow et al., *Flood Routing Analysis for a Failure of Mackay Dam*, EGG-EP-7184, EG&G Idaho, Inc., June 1986.

20. K. N. Koslow letter to J. E. Johnson, Jr., "Transmittal of Peak Elevation at CPP from Addendum to the 1986 Flood Study," KNK-04-88, September 20, 1988.

21. Public Services Company of Colorado, Fort St. Vrain Nuclear Generating Station Final Safety Analysis Report, Volume III, Current revision.

22. Gulf General Atomic, Inc., *Final Design Report for the Fort St. Vrain Fuel Shipping Cask*, GADR-55, Supplement A, May 1970.

23. J. M. Lacy, *Long Term Creep Deformation of ATR Fuel Elements Under Dry Storage Conditions*, B460-94-083, August 15, 1994.

24. A. L. Jones letter to K. F. Childs, "Temperature Estimates for the Fully Loaded IFSF, Rev. 1 of ALJ-03-90," ALJ-05-90, March 9, 1990.

25. D. R. Wenzel, *Radionuclide Inventories for CPP-603 Fuels*, December 9, 1994.

26. A. L. Jones letter to K. F. Childs, "Revised Temperature Estimates for the Fully Loaded IFSF," ALJ-03-90, March 9, 1990.

27. R. L. Moore letter to H. J. Welland, "Heat Transfer Evaluation of the CPP-603 Canning Station," RLM-02-95, July 5, 1995.

28. P. E. Wildenborg letter to Sy Wildman, "FSAR for the Irradiated Fuel Storage Facility: Radionuclide Inventories," PEW-2-82, September 7, 1983.

29. W. D. Wagner letter to K. M. Wendt, "ARMF/CFRMF Assembly Radionuclide Inventory and Radiological Characteristics (WDW-33-95)," WDW-33-95, September 27, 1995.

30. General Atomics, *MHTGR - New Production Reactor, Summary of Experience Base*, GA-A19152, March 1988.

31. Philadelphia Electric Company, *Final Hazards Summary Report*, Peach Bottom Atomic Power Station, Volume III.

32. A.M. Smith letter to B. L. Holmes, "Rover UBM Can Design Document," AMS-11-96, July 15, 1996.

33. R. L. Bratton letter to P.A. Pinson, "Modification of Original Drop Height in EDG-AMG-03-96 for the Rover Can," RLB-05-96, November 1, 1996.

34. Lockheed Martin Idaho Technologies Company, "CAN-SF-1XX Rover Deactivation Engineered Equipment Can, 2.20 I.D. Assembly," Drawing No. 452280, February 1996.

35. M. A. Ebner, L. C. Lewis letter to D. W. Swanson, "Integrity of WAPD Spent Nuclear Fuel in CPP-603 Storage," MAE-11-97/LCLe-07-97, August 11, 1997.

36. PSD 4.12 Addendum B Supplement "ARMF & CRMF Fuels," WIN-107-4.12B-Supplement, October 1997.

37. 10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*, Office of the Federal Register, April 2, 2002.

38. J. R. Arrowood letter to M. A. Stubblefield, H. A. Worle, "INTEC CPP-603 IFSF Facility Radiation Survey Results for PSD 4.12 Validation," October 17, 2001.

39. J. R. Arrowood letter to M. A. Stubblefield, H. A. Worle, "INTEC CPP-603 IFSF Facility Radiation Survey Results for PSD 4.12 Validation," November 25, 2002.

40. HAD-83, "INTEC Fuel Receiving, Storage, and Associated Facilities," Rev. 0, September 6, 2000.

41. Advanced Engineering Consultants, *Structural Appraisal of Underwater Fuel Receiving and Storage Facility CPP-603 Idaho Chemical Processing Plant*, Phase I, December 1992.

42. Advanced Engineering Consultants, *Structural Appraisal of Underwater Fuel Receiving and Storage Facility CPP-603 Idaho Chemical Processing Plant*, Phase II, March 1993.

43. Advanced Engineering Consultants, *Structural Appraisal of Underwater Fuel Receiving and Storage Facility CPP-603 Idaho Chemical Processing Plant*, Phase III, Draft, February 1994.

44. D. T. Clark letter to W. A. Kyes, "Calculations for IFSF Canister 2 ft Drop onto Support Rack," DTC-02-96, April 23, 1996.

45. PRD-112, "Criticality Safety Program Requirements Manual," Rev. 0, November 1, 1995.

46. E. Fast letter to G. T. Paulson, "Criticality Safety Evaluation for the Irradiated Fuel Storage Facility," Fast-09-90, September 13, 1990.

47. D. J. Henrikson, *Criticality Safety Evaluation Using Sample Data for Rover UBM in the Irradiated Fuel Storage Facility*, INEEL/INT-97-00766, July 1997.

48. D. J. Henrikson, *Criticality Safety Evaluation for Rover UBM with Dry Moderator Material and High Uranium Content for IFSF Storage*, INEEL/INT-97-01024, September 1997.

49. E. Fast letter to G. T. Paulson, Criticality Safety Evaluation for the Irradiated Fuels Storage Facility, Fast 09-90, September 13, 1990.

50. K. B. Woods, *Criticality Safety Evaluation for Mapped Array in the Irradiated Fuel Storage Facility*, INEL/INT-97-0078, April 1997.

51. R. R. Jones, *Criticality Safety Evaluation for Mixed Fuel Storage in GSF*, EG&G NRRT-N-90-023, August 1990.

52. K. B. Woods, *Criticality Safety Evaluation for Rover Parka Fuel*, INEEL/INT-98-00978, March 1999.

53. E. Fast letter to P. Fineman, "CSE: Storage of BER-II TRIGA Fuel in IFSF, Addendum," Fast-10-82, March 23, 1982.

54. W. G. Morrison letter to P. Fineman, "CSE: Storage of BER-II TRIGA Fuel in GSR," WGM-02-82, April 8, 1982.

55. J. A. Eggert letter to R. E. Wilson, "CSE - Ft. St. Vrain Canister Lying on Top of the Storage Array in the GSF," JAE-33-79, December 18, 1979.

56. J. B. Briggs, R. R. Jones, *Criticality Safety Calculations for the Graphite Fuel Storage Facility*, EG&G NRRT-N-88-035, September 1988.

57. G. E. Bingham, T. K. Evans, *Final Safety Analysis Report for the Irradiated Fuel Storage Facility*, ICP-1052, January 1976.

58. J. A. Eggert letter to R. E. Wilson, "CSE - Burner Ash & Bed Material Handling in the UFSF Room 107, ISAS Standards Rack, and the On-Site Cask," JAE-7-77, March 16, 1977.

59. R. C. McBroom letter to R. E. Wilson, "Inspection and Repackaging of Rover Fuel Rods in the Mechanical Handling Cave at the Irradiated Fuel Storage Facility," RCM-02-84, January 11, 1984.

60. E. Fast letter to G. T. Paulson, "Storing Broken Fuel Pieces in the GSF," Fast-13-88, September 21, 1988.

61. E. Fast letter to G. T. Paulson, "CSE for Storage of Flooded TORY Fuel in the IFSF," Fast-02-91, February 28, 1991.

62. R. R. Jones *Criticality Safety Evaluation for Flooding TORY II-C Fuel in IFSF Storage Rack*, EG&G NRRT-N-90-056, December 1990.

63. R. R. Jones letter to G. T. Paulson, "Criticality Calculations for Flooded GSF," RRJ-14-88, September 20, 1988.

64. W. G. Morrison letter to Criticality File, "Criticality Safety Evaluation-GSF, Ft. St. Vrain with revised Rover & PB," WGM-7-75, May 23, 1975.

65. J. A. Eggert letter to R. E. Wilson, "TORY II-C in GSF – Fuel Handling Considerations, JAE-11-77, May 20, 1977.

66. W. G. Morrison letter to J. L. Lee, "Storage of TORY II-C in GSF," WGM-4-77, May 4, 1977.

67. E. Fast letter to G. T. Paulson, "CSE for IFSF, Earthquake Case," Fast-10-90, November 9, 1990.

68. R. R. Jones letter to G. T. Paulson, "Criticality Calculations for Reduced Spacing in GSF," RRJ-10-90, October 18, 1990.

69. K. B. Woods, *Criticality Safety Evaluation for Mixed Canisters of Fuels in the IFSF*, INEL-96/096, April 1996.

70. D. J. Henrikson, *Criticality Safety Evaluation for Rover Uranium Bearing Material in the Irradiated Fuel Storage Facility*, INEl-96/269, Revision 1, December 1996.

71. M. N. Neeley, *Criticality Safety Evaluation of MTR Canal Fuel Repackaging and Transfer*, INEL-96/362, March 1997.

72. E. Fast letter to G. T. Paulson, "Storage of Peach Bottom Fuel from Dry Wells in the GSF," FAST-22-88, December 8, 1988.

73. R. E. Wilson letter to R. E. Commander, "PTE-1 Peach Bottom Fuel Element Storage CSE," REW-5-75, December 19, 1975.

74. V. L. Putman, *Criticality Safety Evaluation: FECF Peach Bottom Fuel Relocation*, INEEL/INT-2001-00318, March 2001.

75. PSD 4.12 Series, Section 15, "Technical Standards," Current revision.

76. K. B. Woods, *Criticality Safety Evaluation for Mapped Array in the Irradiated Fuel Storage Facility*, INEL/INT-97-0078, April 1997.

77. D. J. Henrikson, *Criticality Safety Evaluation for Rover UBM in 6M Drums*, INEEL/INT-97-00450, April 1997.

78. D. R. Wenzel letter to W. A. Kyes, "Downwind Doses from a Postulated Criticality Accident in the IFSF," WEN-38-95, December 13, 1995.

79. DOE, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE HDBK-3010-94, U.S. Department of Energy, December 1994.

80. D. R. Wenzel letter to W. A. Kyes, "Downwind Doses from a Postulated Criticality Accident in the IFSF Involving ATR Fuel," WEN-06-96, March 6, 1996.

81. P. E. Wildenborg letter to W. G. Robson, "Radiological Consequences of a Criticality During Liquid Uranium Handling in the CPP-602 Basement," PEW-06-84, April 20, 1984.

82. D. R. Wenzel letter to J. M. Mines, "Downwind Doses from a Postulated Criticality Accident Involving Rover Uranium Bearing Material," WEN-26-96, October 23, 1996.

83. D. R. Wenzel letter to J. M. Mines, "Reevaluated Downwind Doses from a Postulated Criticality Accident Involving Rover Uranium Bearing Material," WEN-19-97, September 24, 1997.

84. D. M. Shell letter to K. F. Childs, "IFSF Canister Temperature Limit," DMS-01-90, March 13, 1990.

85. Harold S. Davis "Effects of High-Temperature Exposure on Concrete," *Transactions of the American Nuclear Society*, Volume 8, Number 1, p. 192, June 1965.

86. R. G. Rahl Letter to E. D. Uldrich, "Shipping Cask Drop Analysis," RGR-3-91, February 4, 1991.

9. OPERATIONAL SAFETY REQUIREMENTS

CONTENTS

9. OPERATIONAL SAFETY REQUIREMENTS

The safe handling and storage of fuels in the IFSF requires several special design features and administrative controls. This section lists those operational safety requirements (OSRs), for which credit is taken in this SAR.

9.1 Engineered Safety Features

The following OSRs are engineered safety features:

1. The roof is capable of precluding water leakage into the facility.

2. The building is capable of withstanding an DBE.

3. The shield walls surrounding the storage area and the fuel handling cave provide protection from direct radiation to facility and collocated workers. In addition, the following engineered safety features provide shielding at certain required penetrations through the concrete structure to keep personnel doses ALARA.

   a. Shielding boxes mounted on the transfer car surface that close the transfer car opening in the south shield wall when the car is either fully in or out of the fuel handling cave.

   b. A lead blanket rack at the transfer car operator station next to the PCS. The drawing number is 099812, and there are 2 sheets.

   c. Shield plates on the personnel access door to the CMA. The drawing number is 500622, and there is 1 sheet.

   d. An earth mound at the cooling air duct penetration near the northwest corner of the storage area. The mound provides shielding that is approximately equivalent to that of the adajcent concrete wall.

4. The storage area rack provides a minimum 22.5-in. center-to-center spacing on a triangular pitch between storage canisters. The handling cave racks provide a minimum 22.5-in. center-to-center spacing on a rectangular pitch between storage canisters. These minimum spacings must be maintained during and following the DBE.

5. The bottom portion of each storage canister containing Rover fuel, Rover UBM, and BER-II TRIGA fuel is water leak-tight.

6. The ventilation system contains replaceable, aerosol testable HEPA filters on the exhaust side.

7. Inserts[1] are provided for storage of Rover fuel, Tory IIC, and BER-II TRIGA fuels.

8. Buckets are provided that limit the number of fuel pieces per layer in a storage canister (as specified in Subsection 4.1.5) and that do not retain water.

9. Carbon-steel canisters (CAN-GSF-101)[2] are constructed of 18-in. Schedule 10 carbon-steel pipe and have the following characteristics:

   a. The capability to exclude the entry of water from the bottom.

   b. A lid that clamps in place and is used for lifting.

   Rover-type fuels (but not Rover UBM) must be stored in this canister type or in the one described in Item 10, below. This canister type may also be used for storing Peach Bottom, Fort St. Vrain, Tory IIC, and BER-II TRIGA fuels.

10. The original stainless-steel canisters (448646-2 marked on upper flange of canister and port position number marked on canister lid)[3] are constructed of 18-in. Schedule 10 stainless-steel pipe and has the following characteristics:

   a. The capability to exclude the entry of water from the bottom.

   b. A lid that clamps in place and is used for lifting. The lid also allows the canister to vent.

   ATR, MURR, ORR, HFBR, WAPD, BMI-Spec, TRIGA-Al, ARMF and CFRMF fuels must be stored in this canister type or in the one described in Item 10, below. This canister type may also be used for storing Peach Bottom, Fort St. Vrain, Tory IIC, and BER-II TRIGA fuels.

11. The light-weight, stainless-steel canister (CAN-GSF-276)[4] is constructed of 18-in. Schedule 10S stainless-steel pipe and has the following characteristics:

   a. The capability to exclude the entry of water from the bottom.

   b. A lid that: clamps in place and is used for lifting; allows the canister to vent; and sheds water, which may otherwise enter from above or laterally.

   This canister type is intended for universal use, accepting any fuel type to be stored in the IFSF. It is mandatory for Rover UBM.

12. The Rover UBM transfer car insert adapter (ADP-GSF-3) is designed to withstand a drop of one fully loaded Rover UBM bucket on top of a second fully loaded Rover UBM bucket in the insert.

13. The Rover UBM bucket handling tool (TD-SF-963-1, TD-SF-963-2) for use in the handling cave is designed to preclude the drop of a Rover UBM bucket by means of a positive latching mechanism. That is, the bucket can be disengaged only when it is not hanging from the tool. The tool is similar in design to that discussed and pictured in Addendum B, but has been modified to withstand the heavier weight of a loaded Rover UBM bucket.

14. The Rover UBM bucket has the following characteristics:

   a. Rover UBM cans cannot be located in the bucket center

   b. The bucket holds a maximum of six Rover UBM cans

c. The annulus formed by the cans in the bucket has a minimum ID of 5.5 in. and a maximum OD of 17.811 in.

15. An engineered method (such as, handling tool and rigging) shall be used to prevent a Rover UBM can from being lifted more than 24.3 ft above the floor below the can.

16. The transfer device (TD-GSF-928-1 or TD-GSF-928-2), which is to be used for Rover fuel tubes in the Rover UBM insert adapter (ADP-GSF-3) in the high load charger insert (INRT-GSF-2) in the transfer car insert, has the following characteristics:

    - No more than eight 2-in. Rover fuel tubes can fit in the transfer device
    - A minimum distance is maintained of at least 2.9 in. from the center of the transfer device to the nearest edge of any Rover fuel tube in it
    - Positions for Rover fuel tubes are equally spaced in 45-degree (±2 degrees) sectors within the transfer device.

    NOTE: The Rover fuel tube transfer devices are not designed for lifting fuel. They are to be used only to provide configuration control of Rover fuel while it is in the transfer car as detailed above.

17. The metal Rover fuel tube has a nominal inside diameter of 2.055 in.

18. Each load path combination delineated in Table 8-1 of Section 8.1.1 has been qualified at a seismic Performance Category 3 (PC-3).

19. For casks, each load path combination delineated in Table 8-1 of Section 8.1.1, if approved, has also been determined to withstand a drop of the cask lid or cask basket/bucket without allowing the cask to fall from the transfer car.

9.2 Administrative Controls

The OSRs that specify the administrative controls for the handling and storage of fuel in the IFSF are given in the 4.12 series of TSs.

9.3 References

1. G. K. Miller letter to F. T. Wilkins, "Evaluation of ATR Fuel Elements for Seismic and Handling Loads Associated with Storage in IFSF Storage Rack," GKM-12-97, October 27, 1997.

2. Drawing No. 448646, "CPP-603 IFSF Fuel Canning Station Canister and Lid Assembly," Rev. 7, August 21, 1995.

3. Drawing No. 055116, "CPP-603 Irradiated Fuel Storage Rover Fuel Storage Canister Insert," Rev. 2, October 29, 1974.

4. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," U.S. Department of Energy, February 8, 1990 (including Change 2, January 7, 1993).