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**FINAL SAFETY ANALYSIS REPORT
FOR THE
IRRADIATED FUELS STORAGE FACILITY**

ALLIED CHEMICAL CORPORATION
IDAHO CHEMICAL PROGRAMS-OPERATIONS OFFICE
IDAHO NATIONAL ENGINEERING LABORATORY

Idaho Falls, Idaho 83401

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**FINAL SAFETY ANALYSIS REPORT
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by
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and
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SUMMARY

A fuel storage facility has been constructed at the Idaho Chemical Processing Plant (ICPP) to provide safe storage for spent fuel from two commercial high temperature gas-cooled reactors, Fort St. Vrain and Peach Bottom, and from the Rover nuclear rocket program. The new facility was built as an addition to the existing fuel storage basin building (CPP-603) to make maximum use of existing facilities and equipment. The completed facility cost approximately \$3 million, and provides dry storage for one core of Peach Bottom fuel (804 elements), 1-1/2 cores of Fort St. Vrain fuel (2200 elements), and the irradiated fuel from the 20 reactors in the Rover program. The facility is designed to permit future expansion at a minimum cost should additional storage space for graphite-type fuels be required.

The spent fuel is stored in closed, 18-in.-diameter, 1/4-in.-thick steel canisters approximately 11 ft long. Each canister contains either four Fort St. Vrain, 12 Peach Bottom, or 210 Rover fuel elements. For heat transfer and criticality reasons, the canisters are stored in an enclosed storage rack in a staggered arrangement, on a 24-in. center-to-center spacing.

Because of the decay heat associated with the stored fuel, approximately 1.2×10^6 Btu/hr for a full facility, the stored fuel is cooled by a forced flow, single-pass air system. This system is capable of supplying a cooling air flow ranging from 0 to 28,000 cfm in 7,000 cfm increments. 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.

To facilitate the required fuel handling and storage tasks, the storage facility is divided into several functional areas, including a cask receiving area, a cask transfer pit, a fuel handling cave, a crane maintenance area, a control room, and a fuel storage area. The facility is equipped with a cask transfer car, a 15-ton crane, a manipulator, and a remotely-operated saw for performing specific fuel handling operations.

A thorough study of the potential hazards associated with the Irradiated Fuels Storage Facility has been completed. This study indicated that the facility is capable of withstanding all credible combinations of internal accidents and pertinent natural forces, including design basis natural phenomena of a 10,000 year flood, a 175-mph tornado, or an earthquake having a bedrock acceleration of 0.33 g and an amplification factor of 1.3, without a loss of integrity or a significant release of radioactive materials.

The design basis accident (DBA) postulated for the facility is a complete loss of cooling air, even though the occurrence of this situation is extremely remote, considering the availability of backup and spare fans and emergency power. The occurrence of the DBA presents neither a radiation nor an activity release hazard. A loss of coolant has no effect upon the fuel or the facility other than resulting in a gradual and constant temperature increase of the stored fuel. The temperature increase is gradual enough that ample time (28

hours minimum) is available for corrective action before an arbitrarily imposed maximum fuel centerline temperature of 1100°F is reached. Therefore, the Irradiated Fuels Storage Facility will provide safe storage for a large number of irradiated graphite fuel elements.

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FINAL SAFETY ANALYSIS REPORT FOR THE IRRADIATED FUELS STORAGE FACILITY

I. INTRODUCTION

The Conceptual Plant Policy announced in the Federal Register of March 12, 1957, and superseded on January 3, 1968, by 33FR30^[1], allows a commercial reactor operator to deliver spent fuel elements to the Atomic Energy Commission for financial settlement if reasonably priced private reprocessing services are unavailable. Presently, there are no commercial reprocessors for High-Temperature Gas-Cooled Reactor (HTGR) fuels, and until an adequate reprocessing load is available no commercial reprocessing plants for these fuels are planned. Recognizing the necessity of receiving and storing irradiated HTGR-type fuels, the AEC's Division of Production and Materials Management requested that facilities be provided at the Idaho Chemical Processing Plant (ICPP) to store one core of Peach Bottom I and 1 ½ cores of Fort St. Vrain fuel, and possibly fuel from the Rover program. The request also indicated that provisions should include future expansion of the facility's fuel storage capacity, and that as far as practical the facility should be capable of receiving and storing fuel from future HTGR's.

Irradiated graphite fuels will be shipped to the fuel storage facility in shielded shipping casks from the Peach Bottom reactor, the Fort St. Vrain reactor, the Rover storage area, and possible future 1100 MW(e) HTGR's. The facility provides areas and equipment to: (a) receive and handle the shipping casks, (b) unload fuel from the casks, (c) transfer the fuel to storage canisters, and (d) store the fuel canisters in a critically safe storage rack. Because of the potential fuel-water reaction associated with graphite-type fuels and the cost of providing safe, wet storage for these fuels, the Irradiated Fuels Storage Facility has been built as a dry storage facility. To remove the decay heat associated with the irradiated fuels, the storage facility is provided with a one-pass cooling-air system that maintains the calculated centerline temperature of the stored fuel below 400°F.

Receipt of Rover fuel at the facility began in April 1975. Present schedules indicate that the initial fuel shipment from the Fort St. Vrain reactor (240 elements) will be received in August 1976; receipt of Peach Bottom I core 2 fuel began in June 1975.

The purpose of the Safety Analysis Report is to present: (a) the design of the fuel storage facility including equipment and instrumentation, and (b) the safety analysis of the facility including a design basis accident. Specifically, the organization of the Safety Analysis Report is as follows: Section II contains a detailed description of the fuel to be stored in the facility and the shielded shipping casks that will be used to transport the fuel; Section III presents a detailed description of the storage facility including the site, the storage structure, and the associated equipment; Section IV briefly describes the instrumentation provided in the facility to insure a safe, effective, and efficient operation; Section V presents the operating sequence from fuel receipt to storage; and Section VI presents a discussion and evaluation of the abnormal occurrences that could take place within the storage facility. The appendices of the report contain detailed supporting information for the material presented in the body of the report.

II. DESCRIPTION OF FUEL AND SHIPPING CASKS

The Irradiated Fuels Storage Facility is specifically designed to provide storage for one core of Peach Bottom and one and one-half cores of Fort St. Vrain fuel, 804 and 2200 elements, respectively. In addition, the facility may also be used for storage of Rover fuel, and possibly at a later date fuel from planned 1100 MW(e) HTGR's. Each fuel type incorporates a unique design and consequently requires a special shipping cask (Table I), and special handling tools and procedures. A description of the fuel element, the shipping cask, and the receiving and handling method for each fuel that will or may be stored in the facility is presented in the following paragraphs.

The following paragraphs also describe the fuels and the before-burnup composition of the most reactive elements. The compositions listed were used as the bases for the criticality calculations. For Peach Bottom and Fort St. Vrain fuels, the shippers values of composition will be used as the actual composition for processing purposes. The values will vary quite widely depending on fuel element location in the core, time in the reactor and other burnup considerations. The Rover fuel will be assayed for U-235 content before shipment and these values will be used to insure that the fuel stored in each canister is within the limits established by the criticality calculations. These assay values will also be used for initial processing accountability.

TABLE I

SPECIFICATIONS FOR FUEL SHIPPING CASKS

Cask	Length (in.)	Maximum Diameter (in.)	Loaded Weight (lb)	Remarks
Fort St. Vrain	209	31	46,500	The cask is top unloading and contains six fuel elements in a spent fuel container.
Peach Bottom	192	42.5	62,800	The cask is mounted on trunnions, is top or bottom unloading, and contains 18 or 19 fuel elements in a shipping basket.
Rover	84	38 x 38	42,000	The cask is a Rover shipping cask, Model LASL J-9, with a special poisoned cask insert with storage space for 175 fuel elements in 25 fuel tubes.
Future HTGR	209	102 to 104	320,000	The cask will be top unloading, will contain 72 Fort St. Vrain type fuel elements, and will be shipped only by railroad flatcar.
Fuel Transfer Cask ^(a)	100	30	30,000	When needed, the cask will be fabricated and used to transfer fuel from the storage facility to the graphite processing facility. The cask will contain either four Fort St. Vrain or twelve Peach Bottom elements in a storage canister.

(a) The specifications for this cask are only approximate.

1. PEACH BOTTOM

A Peach Bottom fuel element (Figure 1) is 12 ft long, 3.5 in. in diameter and weighs approximately 90 lb. Each element consists of an upper reflector section, a fuel-bearing center section, a lower reflector section, and an internal fission product trap. All components of a Peach Bottom element are constructed of graphite except the fuel compacts contained in the fuel-bearing center section, the burnable poison compacts placed in the hollow center spines of certain elements, and 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) consist of uranium carbide (93.15% enriched) and thorium carbide substrates coated with pyrolytic carbon 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. The most reactive fuel element has the following composition: (compacts only)

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

(Additional carbon in the sleeve, reflectors, and spine was included in the criticality calculations.)

The Peach Bottom fuel elements are transferred from the reactor to the storage facility in the Peach Bottom fuel shipping cask^[2] shown in Figure 2. Each shipment contains either 18 or 19 fuel elements sealed in individual aluminum alloy storage cans. For shipping, the cans are arranged in a special aluminum basket that maintains the desired fuel element spacing. As received, i.e., sealed in an aluminum storage can, a fuel unit^(a) weighs about 150 lb; a fully-loaded shipping basket weighs 3400 lb.

(a) An element sealed in an aluminum storage can.

Fig. 1 Peach Bottom fuel element.

Fig. 2 Peach Bottom fuel shipping cask.

Special tools are provided for handling cask, the shipping basket, the aluminum storage cans, and the fuel elements. The tools are designed to be used with either the crane (Section III.7.5) or the manipulator (Section III.7.6).

2. FORT ST. VRAIN

A Fort St. Vrain fuel element (Figure 3) consists of a 300 lb hexagonal, needle-coke graphite block, 14.2 in. across the flats and 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 about 0.3 in. of the bottom face. The fuel holes occupy alternating positions with the coolant channels in a triangular array within the element structure and contain the active fuel. After the fuel is inserted in a fuel hole, the hole is sealed with a graphite plug cemented into place.

The fresh fuel itself is in the form of carbide particles coated with layers of pyrolytic carbon and silicon carbide, loosely bonded by a carbonaceous matrix material into fuel sticks. The fuel bed contains a homogeneous mixture of two types of particles, called fissile and fertile. Fresh fissile particles contain thorium and 93.5% enriched uranium; fresh fertile particles contain only thorium. The important parameters of fresh particles are:

<u>Parameter</u>	<u>Fissile</u>	<u>Fertile</u>
Th/U (atomic ratio)	4.25	All Th
Particle Composition	(Th/U)C ₂	Th C ₂
Average Fuel Particle		
Diameter, μ	200	450
Average Total Coating		
Thickness, μ	130	140

Besides fission products, the irradiated fuel contains thorium, U-233, U-235, other uranium isotopes, and a small quantity of plutonium. In the fertile particles, the fissile material is essentially U-233, while the fissile particles contain the residual U-235 and bred U-233.

The effective fissile material enrichment (U-235/U±Th) in fresh fuel for the initial core and reload segments varies between 2 and 12% depending upon radial and axial fuel zoning requirements. The most reactive fresh fuel elements have the following composition:

Th-232	11.25kg
U-235	1.31kg
U-238	0.078kg
Silcon	4.63kg
Carbon	111.3kg

An irradiated element contains a smaller amount of fissile material since the conversion ratio of the reactor is less than unity.

Fig. 3 Fort St. Vrain fuel element.

The irradiated fuel elements are transferred from the reactor to the storage facility in the Fort St. Vrain spent fuel container and shipping cask^[3] shown in Figure 4. Each shipment consists of six fuel elements stacked vertically in a stainless steel spent-fuel container placed in the shipping cask. The spent-fuel container is approximately 18 in. in diameter and 16-ft long, and when loaded with fuel weighs 3,680 lb.

The spent-fuel container and fuel elements are handled with the facility crane or the manipulator hoist using special electrically operated, remote handling tools.

3. ROVER

The Rover nuclear rocket fuel is composed of a graphite matrix that contains uranium dispersed through the fuel element either as uncoated or pyrolytic-carbon-coated uranium-dicarbide fuel particles. A protective coating of niobium carbide is present on the cooling channel surfaces of most of the fuel elements. There are two basic types of fuel which are described as Rover fuel: plates and rods. The Kiwi A fuel is composed of flat plates of graphite and enriched uranium. Each plate is 1/4 in. thick and 7-1/2 in. long. The plates are of various widths, i.e., 4.85 in. to 7.90 in. There are 960 plates of this type which will be crushed and placed in cardboard tubes. The remainder of the fuel, approximately 26,000 elements, is the rod form. Although there are some short rod-type elements, most of the rods are approximately 52 in. long; thus, a standard Rover element is considered to be a 52 in. long rod, hexagonal in cross section and 3/4 in. across the flats. One Kiwi A fuel plate is considered to be equivalent to one standard Rover element. Six of the short rod-type elements from Kiwi A and Kiwi A3 are equivalent to one standard Rover rod. A complete listing of the Rover fuels is shown in Table II.

The Rover fuels, containing about 2600 kg of 93% enriched uranium are presently stored in a fuel storage area at the Nevada Test Site, and will be transferred to the Irradiated Fuels Storage Facility. The Rover fuel is lightly irradiated with a minimum cooling time of six years; the highest burnup was 0.4%. Thus, the Rover fuel has both low radiation levels and low heat generation rates. The most reactive fuel elements contain a maximum concentration of 600 mg of U/cc of fuel element. This yields a maximum of 160 g of U-235 per standard Rover element for the most reactive elements.

The Rover elements are received in special shielded shipping casks^(a) (Figure 5) with the elements contained in cardboard tubes. Each tube contains a maximum of seven equivalent elements, and each cask contains 25 tubes arranged in a poisoned cask insert (Figure 6). The cardboard tubes are stored in the Irradiated Fuels Storage Facility in canister inserts which nest in two tiers inside a standard storage canister. Each canister insert will contain a maximum of 15 cardboard tubes. Each storage canister will then contain a maximum of 30 cardboard tubes or 210 equivalent Rover elements. The cardboard tubes are 53.75 in. long, 2.75-in. OD, 3/32-in. wall thickness with a 7/8-in. thick wooden plug in each end. The cardboard density has been measured at 0.72 g/cc. The average weight of a cardboard tube measured at Nuclear Rocket Development Station, Nevada Test Site is 633g.

(a) LASL J-9 casks.

Fig. 4 Fort St. Vrain spent fuel container and shipping cask.

TABLE II
ROVER FUEL SUMMARY^[10]

No.	Reactor	No. Elem.	Size ^(a)	No. Holes ^(a)
1.	KIWI A	960	See Text	N. A.
2.	KIWI A ¹	4800	3/4 D. x 8 1/2 L.	4 (3/16 D.)
3.	KIWI A3	4800	3/4 D. x 8 1/2 L.	4 (3/16 D.)
4.	KIWI B-1A	1147	3/4 D. x 50 L.	7 (3/16 D.)
5.	KIWI B-1B	1147	3/4 D. x 50 L.	7 (3/16 D.)
6.	KIWI B-4A	1355	3/4 HEX. x 50 L.	19 (0.100 D.)
7.	KIWI B-4D (202)	1542	3/4 HEX. x 51.88 L.	19 (0.100 D.)
8.	KIWI B-4E (301)	1542	3/4 HEX. x 51.88 L.	19 (0.100 D.)
9.	NRX-A2	1626	3/4 HEX. x 52 L.	19 (0.100 D.)
10.	TNT	1542	3/4 HEX. x 51.88 L.	19 (0.100 D.)
11.	NRX-A3	1626	3/4 HEX. x 52 L.	19 (0.100 D.)
12.	PHOEBUS 1A	1534	3/4 HEX. x 52 L.	19 (0.100 D.)
13.	NRX-A4	1584	3/4 HEX. x 52 L.	19 (0.100 D.)
14.	NRX-A5	1584	3/4 HEX. x 52 L.	19 (0.100 D.)
15.	PHOEBUS 1B	1498	3/4 HEX. x 52 L.	19 (0.100 D.)
16.	NRX-A6	1584	3/4 HEX. x 52 L.	19 (0.100 D.)
17.	PHOEBUS 2A	4068	3/4 HEX. x 52 L.	19 (0.110 D.)
18.	PEWEE I	402	3/4 HEX. x 52 L.	19 (0.110 D.)
19.	XE-2	1584	3/4 HEX. x 52 L.	19 (0.100 D.)
20.	NU. FURNACE 1	49	3/4 HEX. x 52 L.	19 (0.110 D.)
TOTAL		27014 ^(b)		

(a) All dimensions are in inches

(b) Does not include KIWI A and assumes approximately 800 elements equivalent to 52 inches long for each of the KIWI A¹ and KIWI A3 reactors.

Fig 5 Rover fuel shipping cask

Fig. 6 Rover fuel shipping cask insert.

4. FUTURE HTGR's

Future high-temperature gas-cooled reactors are designated 1100 reactors because each is designed to produce an electrical output of approximately 1100 MW. Fuel elements from these reactors will be essentially identical to those from the Fort St. Vrain reactor and will be handled in the same manner. The shipping cask, however, will differ significantly.

The estimated annual fuel element discharge rate from an 1100 reactor is approximately 1,000 elements, compared to an annual Fort St. Vrain discharge rate of about 240 elements. The significantly higher fuel discharge rate requires the use of a much larger fuel transfer cask. A tentative design for a suitable transfer cask having a 72 element capacity (12 spent fuel containers with six elements in each container) is shown in Figure 7. The cask is transported only by railroad flatcar.

The storage facility design bases did not include storage space for 1100-reactor fuel. However, the facility has been built with sufficient flexibility to permit receiving and storing this fuel without extensive facility modifications. Specific facility provisions made to permit handling the 1100 fuel include:

1. Constructing the CPP-603 crane extension with sufficient capacity to accept a 160-ton-capacity bridge crane.
2. Providing a cask transfer pit wide enough and a cask transfer car large enough to accept the conceptual 1100 shipping cask.
3. Installing a 15-ton crane in the storage facility to permit handling the lid of the 1100 shipping cask.
4. Installing a removable end wall in the fuel storage area to permit future expansion of the storage area and provide storage space.

Should this fuel ever be received, an analysis will have to be performed, reviewed, and approved to insure that the fuel can be safely stored in the facility.

III. FACILITY DESCRIPTION

The Irradiated Fuels Storage Facility has been constructed within the confines of the ICPP exclusion area as shown in Figure 8. The facility was built as an extension to the existing fuel storage basin building (CPP-603) to realize maximum use of existing facilities, and has become an integral part of the ICPP fuel storage complex.

Fig. 7 Proposed HTGR fuel element shipping cask.

Fig. 8 Location of the Irradiated Fuels Storage Facility at the Idaho Chemical Processing Plant.

1. SITE

The Idaho Chemical Processing Plant (ICPP) is located in the Idaho National Engineering Laboratory (INEL) near Idaho Falls, Idaho. The INEL covers about 894 square miles of the central-northern edge of the Southeastern Idaho counties of Bingham, Bonneville, Butte, Clark, and Jefferson. The terrain is predominantly flat with an average one percent slope from southwest to northeast. The average elevation is 5,000 ft above sea level.

The ICPP is an exclusion area of 97 acres within which are located facilities to store and reprocess reactor fuel elements, and to treat solid, liquid, and gaseous radioactive wastes generated during fuel reprocessing operations.

The ICPP fuel storage complex is located in the southwest corner of the exclusion area enclosed by the ICPP perimeter fence. The storage complex consists of three interconnected fuel storage basins, a fuel receiving area, a fuel element cutting facility, and the Irradiated Fuels Storage Facility. The storage complex is served by both truck and rail transportation.

2. SEISMOLOGY^[4]

The seismic record of southeastern Idaho is short: the first recorded earthquake occurred in 1884. Since then, there have been approximately 25 quakes of sufficient intensity to be classed as Modified Mercalli intensity V or higher, i.e., of sufficient intensity to be noticed by nearly everyone in the area. None of these quakes originated within approximately 80 miles of ICPP. The strongest recorded earthquake occurred in August 1959 and had an epicenter estimated to be near the northwest corner of Yellowstone Park, approximately 100 miles northeast of the INEL. This quake measured 7.1 on the Richter Scale, but caused no structural damage at the INEL. The INEL is classified within Seismic Risk Zone 3 of the Uniform Building Code, 1970 edition.

3. HYDROLOGY^[5, 6, 7]

The INEL is located at the central-northern edge of the semi-arid Snake River Plain in Southern Idaho, adjacent to the southern foothills of the Lemhi and Lost River mountain ranges.

The INEL has no well-defined, integrated, surface-water drainage system, and is not crossed by perennial streams. However, the INEL overlays a natural underground reservoir of water, ranging from 200 to over 800 ft to the water table, having an estimated lateral flow of not less than 2,000 ft³/sec, or about 1.3 billion gal/day.

Very little water enters the INEL by surface inflow, and no water leaves by surface outflow except for minor local slope runoff. The named drainage ways into the INEL are the Big Lost River, the Little Lost River, and Birch Creek. Most of the water in these

drainages is diverted for irrigation purposes, and only the Big Lost River flows onto the INEL: this flow disappears into a number of sinks within the INEL area. Flooding hazard from the Big Lost River has largely been eliminated by diverting the water to an infiltration basin located at the south end of the station. Flood hazard within the INEL is thus relatively small, although an infrequent local cloudburst or melting snow condition might produce a heavy flash runoff. The fuel storage facility is located about one mile south of the Big Lost River and approximately 10 ft above the river bed. Reference 6 concludes that a 10,000 year, 30,000 cfs flood at ICPP would not cause serious flooding. The 30,000 cfs flood would result in flood water at elevation 4916.6 ft mean sea level. This is 1.6 ft below the grade level of 4918.2 ft at CPP-603.

4. METEOROLOGY^[8]

The INEL wind direction is heavily influenced by the surrounding mountains which by their orientation channel the winds. At times, therefore, the wind pattern over the INEL can be quite complex, with different areas of the station experiencing somewhat different winds.

The INEL lies in the belt of prevailing westerly winds that are channeled upon entering the valley, normally in a SW or WSW direction. When the prevailing westerlies at the gradient level (5,000 ft above the surface) are strong, the winds channeled into the confined region between the mountains become very strong, and the INEL experiences some of its highest winds. The greatest frequency of these winds is in the spring. While the winds are predominantly "fair weather" phenomena, they can also occur during cloudy periods.

Figures 9 and 10 show the overall wind rates by both season and total period for the Central Facilities Area at the 20- and 250-ft levels, respectively. The wind roses show the frequency in percent of occurrence of winds from 16 directions ($22\frac{1}{2}^\circ$ sector) for selected speed classes and calm periods. Winds are always recorded as the direction *from which* the wind is blowing, i.e., a north wind blows from north to south. From the wind roses, some generalizations about the INEL wind patterns are immediately evident:

1. The wind channeling effect. Winds are primarily from the WSW-SW and the NNE-NE.
2. The very small percentage of winds from the SE and NW.
3. The higher wind speeds and less frequent calms at the 250 ft level.
4. The higher frequency of calm periods during the winter.
5. The higher overall frequency of winds from the southwest quarter of the compass.

Fig. 9 CFA 20-ft level wind roses, January 1950 through May 1962.

Fig. 10 CFA 250-ft level wind roses, July 1951 through May 1962.

The average wind speeds for CFA at the 20- and 250-ft levels, and the highest hourly average wind speeds recorded by months and annually are listed in Table III. The higher level has higher speeds because of the decreased effects of surface friction with height.

The peak gusts or highest instantaneous wind speeds ever recorded at Central Facilities and Test Area North are listed by months in Table IV. While strong gusts may be a result of pressure gradients from large-scale systems, they may also result from a thunderstorm. Since thunderstorms can be found at any location and move in any direction, very strong gusts can be expected from any direction on the compass.

5. FACILITY

The Irradiated Fuels Storage Facility, a drawing of which is shown in Figure 11, is constructed almost entirely of noncombustible materials, mostly steel and concrete. The facility is divided by concrete shielding walls into a number of functional areas, each designed and equipped for specific tasks and purposes. A description of each area and its function is provided in the following paragraphs.

5.1 Cask Receiving Area

The cask receiving area is a 70-ft extension of the west end of the existing CPP-603 cask receiving area, as shown in Figure 12. By extending the present facility, the existing 75-ton crane and the railroad spur can serve both the old and the new cask receiving areas. The capacity of the existing CPP-603 crane is 75 tons. The building extension, however, was built to accommodate a 160-ton crane. Thus, should future fuel shipments require handling loads in excess of 75 tons, the required capacity may be obtained by purchasing a new crane bridge and installing it on the existing rails.

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. This area also contains provisions for a shielding door and a transfer dolly to be designed, built, installed, and used at a later date to transfer fuel storage canisters from the storage facility to a transfer cask for shipment to the graphite process headend.

The cask transfer pit, shown in Figure 13, is approximately 10 ft wide, 44 ft long, and 18 ft deep, and contains the cask transfer car. Approximately one-half the pit is located in the cask receiving area, and the other half in the fuel handling cave. A liquid-waste sump is located in the bottom of the cask transfer pit so that any liquids entering the pit from either the fuels storage area, the fuel handling cave, or the cask receiving area will flow into the sump and be pumped to the CPP-603 process waste system for collection and eventual evaporation.

The truck ramp lies parallel to the railroad tracks and extends approximately five feet below grade. The length of the Fort St. Vrain fuel shipping cask (18 ft) and the limited clearance of the 75-ton crane (24 ft) prohibit transferring this cask directly from a transport vehicle to the cask transfer car. Therefore, the loaded transport truck must be positioned on the unloading ramp to provide the additional clearance required to remove the cask from the vehicle.

TABLE III

HOURLY AVERAGE WINDSPEEDS(mph), CFA

	Average Speed(mph)		Highest Maximum Hourly Average Speed(mph)			
	<u>20-Ft Level</u> ^(a)	<u>250-Ft Level</u> ^(b)	<u>20-Ft Level</u> ^(c)		<u>250-Ft Level</u> ^(d)	
			<u>Speed</u>	<u>Direction</u>	<u>Speed</u>	<u>Direction</u>
January	5.6	9.7	48	WSW	65	SW
February	6.9	11.3	36	SW	52	SWS
March	8.7	13.8	51	WSW	67	WSW
April	9.3	14.6	39	WSW	49	WSW-SW
May	9.3	14.3	41	SW	47	WSW-SW
June	8.9	14.2	36	SW	46	SW
July	8.0	13.5	35	WSW	47	WSW
August	7.7	13.1	40	WSW	54	SW
September	7.2	12.8	42	WSW	56	WSW
October	6.8	12.3	44	WSW	58	WSW
November	6.4	11.6	40	WSW	54	WSW
December	5.1	9.6	43	SW	56	SW
Annual	7.5	12.6	51	WSW	67	WSW

(a) April 1950 through October 1964

(b) July 1951 through October 1964

(c) April 1950 through January 1972

(d) July 1951 through January 1972

TABLE IV

PEAK GUSTS (mph), CFA AND TAN

	CFA				TAN			
	20-Ft Level ^(a)		250-Ft Level ^(b)		20-Ft Level ^(c)		150-Ft Level ^(d)	
	<u>Direction</u>	<u>Speed</u>	<u>Direction</u>	<u>Speed</u>	<u>Direction</u>	<u>Speed</u>	<u>Direction</u>	<u>Speed</u>
January	SW	70	SW	79	S	58	NNW	64
February	WSW	60	SW	66	N&SSW	62	SW	59
March	WSW	78	SW	84	N	65	SW	73
April	S	67	SW	62	SSW	60	NW	76
May	SW	62	SSW	67	NNW	60	NNW	66
June	SSW	60	SSW	75	S	67	SW	76
July	N	68	S	66	W	60	W	73
August	WSW	62	SW	72	SSW	64	WSW	68
September	WSW	61	WSW	70	SSW	54	W	73
October	WSW	66	WSW	76	NNW	63	NW	64
November	WSW-SW	60	WSW	70	SW	59	NNW	78
December	SW	64	SSW	80	NNW	62	NNW	68
Period of Record	WSW	78	SW	84	S	67	NNW	78

(a) April 1950 through January 1972

(b) July 1951 through January 1972

(c) July 1950 through April 1961

(d) April 1956 through April 1961

IRRADIATED FUELS STORAGE FACILITY

Fig 11 Isometric of the Irradiated Fuels Storage Facility

Fig. 12 Irradiated Fuels Storage Facility, plain view.

Fig. 13 Irradiated Fuels Storage Facility, section C.

The primary function performed in the cask receiving area is the receipt of full fuel shipping casks^(a) from the reactors and returning empty fuel shipping casks to the reactors, and at a later date transferring fuel from storage to the graphite process headend. Specifically, incoming casks are transferred from the transport vehicle to the cask transfer car, and the cask top-head closure bolts removed. Following fuel unloading, outgoing casks are checked for contamination and the top-head closure bolts are replaced. When, at a later date, fuel is transferred from storage to a processing headend, a fuel transfer cask similar to that shown in Figure 14 and explained in Section V, or a cask similar to a shipping cask would be loaded in the handling cave, carried in the transfer car to the cask receiving area and then transferred to the process headend.

At the present time, a port in the south wall which was designed to be used with the cask shown in Figure 14 is blocked off. The port is shielded with 11 in. of lead bricks and the opening is covered on both sides with steel plate and is sealed around the perimeter to prevent air leakage. At a later date, the port can be opened up for use with a horizontal cask if necessary.

5.2 Fuel Handling Cave

Several functions are performed in the fuel handling cave, including transferring fuel from shipping casks to storage canisters, preparing fuel elements for storage and processing, and, in the future, transferring fuel from storage to processing.

The fuel handling cave is equipped with a manipulator for fuel handling; a remotely operated saw for fuel cutting; a vacuum cleaner system for collecting graphite dust and particles generated during cutting and handling operations; floor wells for temporarily storing full or empty fuel element baskets, spent fuel containers, or fuel storage canisters; and a shuttle bin for transferring canisters between the fuel handling cave and the fuel storage area.

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 are sized for Peach Bottom fuel shipping baskets and are 26 in. in diameter and approximately 13 ft deep; two wells are sized for Fort St. Vrain and 1100 HTGR shipping containers and are 20.5 in. in diameter and approximately 16 ft deep; the remaining 11 wells are sized for standard IFSF storage canister and are 20.5 in. in diameter and approximately 13 ft deep. If smaller containers are ever placed in the wells, adapter sleeves will be used to reduce the size of the wells. When not in use, the floor wells are covered with removable steel cover plates. A 2-in. diameter drain line connects each floor well to a 4-in. diameter common header that discharges to the cask transfer pit sump. To prevent any possible accumulation of water in the storage area or handling cave, the drain valves will be kept locked open.

(a) All fuel transfer casks are transported by truck, except the proposed "1100" cask which will be transported by rail.

Fig. 14 Conceptual fuel transfer cask.

Since the sawing operation is performed directly over an open floor well, it is possible to drop a complete element into a floor well. It is also possible to have pieces of broken elements fall into a floor well if an element were dropped. A floor well insert has been constructed which will fit inside a floor well to aid in recovery of broken fuel elements or pieces of fuel elements.

To facilitate future 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.

Due to the possible chemical reaction between water and carbides and the possibility of thereby releasing fission products from the carbide fuel particles, no water supply lines are present in the handling cave. Water is not permitted in the cave while fuel is present. It may be necessary to use water for decontamination of the cave, but all fuel will be removed first.

A shielding window permits control room viewing of handling cave activities, and a labyrinth connects the cave to the crane maintenance area to permit equipment removal and replacement.

5.3 Control Room

A control room has been built as an integral part of the fuel storage facility. Because the 15-ton storage facility crane must have access to all regions of the facility, it must pass over the control room. To permit crane access, and still provide radiation protection to operating personnel, the control room has been constructed with its own shielding roof. To aid the facility operators in fuel handling operations (especially viewing), the control room floor is located about 8 ft above grade.

All fuel handling operations, including transferring, decanning, and cutting are performed remotely from the control room. In addition, the 15-ton crane, the manipulator, the saw, the vacuum cleaner, and the cask transfer car, as well as the television, heating and ventilating, communication, and lighting systems, are all operated and controlled from the control room.

Two shielding windows and a television monitor are provided in the control room to permit viewing handling cave and fuel storage area operations. The shielding windows are installed in the control room walls so that one window overlooks the fuel handling cave and the other, the fuel storage area. The television camera is mounted on the trolley of the 15-ton crane so that continuous surveillance of the area in which the crane is operating is provided, especially the point at which the crane hook engages a storage canister lifting bail. Areas of the facility that cannot be viewed directly through the shielding windows or indirectly with the television system will be observed with mirrors.

5.4 Instrument Room

As shown in Figure 13, a concrete floor divides the control room area into an upper level control room and a lower level instrument room. Two constant air monitors (CAM's) and the master control panel for the crane, the manipulator, and the saw are all located in the area.

5.5 Fuel Storage Area

The fuel storage area of the facility (Figure 15) contains the carbon steel storage rack (Figures 16, 17, 18, 19, and 20) that provides both spacing and support for the 636,18-in. diameter, 11-ft-long fuel storage canisters. The storage rack maintains the canisters in the staggered, 24-in. center-to-center spacing necessary 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, except for the canister holes, is completely enclosed with sheet metal so that in addition to providing canister positioning and support, the rack also serves as the plenum for cooling air. Most of the cooling air is supplied at one end of the rack structure and exhausted at the other end so that positive cooling of the stored canisters is obtained. A small flow of air is directed above the rack to prevent dead air spaces and hot spots. The storage canisters are provided with tight-fitting lids to prevent the cooling air from having direct contact with the stored fuel. See Section III.8 for details of the cooling air system.

The upper 18 ft of the west wall of the fuel storage area is fabricated in removable sections so that if future expansion of the facility becomes necessary, the expansion may be accomplished with a minimum of time and effort.

To prevent the possibility of a fuel-water reaction, water and water lines are excluded from the storage area.

5.6 Crane Maintenance Area

The crane maintenance area (Figures 12 and 15) is approximately 13 ft wide and extends the entire width of the east end of the fuel storage facility. This area is expected to have a radiation level less than 30 mR/hr and will be a controlled access area. It is provided to permit contact maintenance on the 15-ton overhead crane, the TV camera, the manipulator, the saw head, and all other facility equipment that is designed to be moved by remote methods into this area. A labyrinth connects the crane maintenance area to the handling cave to permit passage of equipment between the cave and the maintenance area, yet maintain shielding integrity.

SECTION A

Fig. 15 Irradiated Fuels Storage Facility, section A.

LOCATION PLAN

SCALE: 1/4" = 1'-0"

Fig. 16 Fuel storage rack, storage locations.

ACC-A-0560

Fig. 17 Fuel storage rack.

REFERENCE DWGS.
FUEL STORAGE RACK ASSY - DWG M-17
" " " " DETAILS - DWG M-19
" " " " - DWG M-20
" " " " - DWG M-21

Fig. 18 Fuel storage rack construction details.

Fig 19 Fuel storage rack construction.

Fig. 20 Fuel storage area, isometric.

A 6-ft square, stainless steel lined decontamination pad, supplied with water, air, and steam, is provided in the crane maintenance area for use in decontaminating equipment removed from the fuel handling cave. Liquid wastes from the decontamination pad are piped through the existing CPP-603 floor drain system to VES-SFE-20, the waste tank at Building CPP-642. From VES-SFE-20, the wastes are pumped to the waste evaporator at Building CPP-604 for evaporation and ultimate disposal.

The roof of the crane maintenance area contains a 6-ft by 6-ft 9-in. concrete roof hatch to permit access to the facility with a mobile crane hook, should access become necessary for equipment removal or replacement. The roof hatch also allows removal of the manipulator trolley and arm as a unit should extensive maintenance or total replacement be necessary.

6. SHIELDING

The Irradiated Fuels Storage Facility is designed so that handling and storage of fuel presents no radiological hazard to either personnel or the environment. Shielding requirements for the storage facility were determined by dividing the facility into functional areas and assigning access designations and acceptable (based on ERDA standards, Reference 9) radiation levels to each area as shown in Table V. These radiation levels permit controlled access to all areas of the facility except the fuel storage area. Calculations^(a) were then performed to determine the shielding required to reduce the expected radiation levels in each area to the acceptable level. The results of the shielding calculations are shown in Table VI.

A movable shielding door (Fig. 15) that closes the opening between the top of a concrete shielding partition and the roof of the storage facility is provided between the fuel storage area and the remainder of the facility. The door is constructed of three, 14-ft-long, 11-in.-thick carbon steel sections and reduces the radiation levels in the fuel handling cave and the crane maintenance area to approximately 200 mR/hr and 30 mR/hr, respectively. When reduced radiation levels in the cave and crane maintenance areas are not needed, i.e., when entrance to the facility is not required, the door can be retracted through the north wall of the facility into a special enclosure.

Two lead-glass-shielded, oil-filled viewing windows are provided in the control room to permit viewing the fuel handling operations in the storage facility. One window allows viewing the fuel handling cave, the other the fuel storage area. Each window is approximately 37 in. high, 41 in. wide, and 4 ft thick, and is designed to provide a 130° field of view. A protective 3/4-in.-thick lead plate that can be remotely closed to cover the fuel storage area shielding window is provided to reduce the direct radiation dose to the window when the window is not in use and prolong the life of the window. A small, control-room-mounted electric motor, through a shaft and gear arrangement, is used to position this door. For strength, the lead door is encased in 1/4-in.-thick stainless plate. The encasement will also prevent lead slumping at storage area temperatures.

(a) Details of the shielding calculations are presented in Appendix C.

TABLE V

PREDICTED FACILITY RADIATION LEVELS

Area	Designation	Maximum Predicted Radiation Level	Conditions	Shielding Method
1. All ground level areas external to the storage facility	Full time access	2.5 mR/hr at ground level	The storage area filled ^(a) with fuel and one shipment ^(b) of fuel in the handling cave.	Concrete walls and concrete roof.
2. Roof	Limited access	~50 mR/hr	Same as (1).	Concrete roof.
3. Control and Instrument Rooms	Continual occupancy	0.25 mR/hr	Same as (1).	Concrete walls and roof.
4. Crane Maintenance	Limited access	30 mR/hr ^(c)	Same as (1) except no fuel in the handling cave.	Concrete partition and movable steel shielding door.
5. Fuel Handling Cave	Limited access	2 R/hr ^(c)	Same as (1) except no fuel in the handling cave.	Concrete partition and movable steel shielding door.

(a) 2276 Fort St. Vrain and 804 Peach Bottom elements.

(b) Six Fort St. Vrain or 19 Peach Bottom fuel elements suspended from the crane with the container centerline 4 ft above the cave floor.

(c) With the movable steel shielding door closed.

TABLE VI
CALCULATED SHIELDING THICKNESS

<u>Item</u>	<u>Material</u>	<u>Thickness (ft)</u>
External fuel storage area walls	Concrete	3 to 4.75
All other external walls	Concrete	2.75
Control room walls	Concrete	4.75 to 4.92
Facility roof	Concrete	~3
Control room ceiling	Concrete	2
Movable shielding door	Steel	0.92
Cask transfer car	Steel	1
Fuel handling cave shielding wall	Concrete	3
Crane maintenance area shielding wall	Concrete	3
Shuttle bin	Lead	0.5

The steel cask transfer car (Section III.7.7) provides shielding between the fuel handling cave and the cask receiving area. Regardless of the position of the car, as long as a cask is positioned in the adapter plate, or the blind adapter plate installed, the cask receiving area is adequately shielded. Administrative procedures govern operation of the cask transfer car.

7. EQUIPMENT

A considerable amount of equipment is available in the fuel storage facility to enable the irradiated graphite fuels to be safely and effectively handled and stored. A brief description of each piece of equipment and its purpose is presented in the following paragraphs. The control systems are discussed in Section IV.3.

7.1 Fuel Storage Canisters and Containers

Fuel is received and stored in several different containers. To avoid confusion and establish consistent terminology, the terms used throughout this report include:

- a. *Storage Canister* - An 18-in. diameter carbon steel container used to store fuel in the Irradiated Fuels Storage Facility.

- b. *Can* - An aluminum can containing an irradiated Peach Bottom fuel element.
- c. *Shipping Basket* - An aluminum basket that positions the Peach Bottom cans (containing fuel elements) in the fuel shipping casks.
- d. *Spent Fuel Container* - A stainless steel container that positions six Fort St. Vrain fuel elements in the fuel shipping cask.
- e. *Canister Insert* - A 16-in. diameter carbon steel container, which fits inside a storage canister, and holds Rover fuel elements in two tiers.
- f. *Rover Poisoned Cask Insert* - An aluminum box, 15-1/2 in. x 15-1/2 in. x 60.5 in. with 25 steel tubes surrounded by boron carbide. Used to contain 25 cardboard tubes of Rover fuel during shipment. (see Figure 6).
- g. *Rover Pedestal* - A carbon steel frame made of two half sections of 20-in. diameter pipe set side by side on a base. Used to position Rover canister inserts at a 60° angle for loading. This angle helps prevent "jack strawing" and allows the operator to see down into the canister insert.

The storage canisters (Figure 21) are made of 1/4-in. thick carbon steel, are 11 ft long, and are used to store the graphite fuel in the Irradiated Fuels Storage Facility. Each canister provides storage for either 12 Peach Bottom or 4 Fort St. Vrain fuel elements, or 30 cardboard tubes^(a) of Rover fuel. The canisters are provided with tight-fitting lids to minimize air and/or particulate leakage and with lifting bails to permit remote handling with the crane or the manipulator. A metal identification tag containing a raised letter and number is attached to each lid. The letter and number identify a specific storage rack position, and provide identification of stored materials. A total of 636 storage canisters is provided. Several dust-tight lids (standard lids provided with spring steel gaskets) are provided for use with cans containing graphite dust or broken elements.

7.2 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 is transferred between the two areas by means of the fuel shuttle bin shown in Figure 15. The shuttle bin is a remotely-controlled, electrically-driven container mounted on wheels that can accept storage canisters up to 31 in. in diameter and 13 ft long. An adapter plate reduces the container diameter to 18-1/2 in. to better fit the storage canisters. The shuttle bin container operates on rails installed in the shuttle bin pit that extend beneath the shielding wall that separates the cave and the fuel storage area. By activating the shuttle bin drive, the bin can be positioned in the fuel storage area or the handling cave, and the facility crane used to insert or remove fuel storage canisters. A 6-in.-thick carbon steel encased lead plate 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.

(a) Each tube contains a maximum of seven equivalent standard Rover fuel elements.

Fig. 21 Storage canister.

To transfer fuel from the handling cave to the storage area, the shuttle bin is positioned in the handling cave and a canister of fuel placed in the bin container. The bin drive is then activated moving the bin into the fuel storage area. The fuel canister is then removed from the shuttle bin and placed in a storage rack position with the use of the 15-ton crane.

The shuttle bin is remotely controlled from the facility control room and is provided with both movement and position indicating lights. The bin is also connected to a sliding metal plate that covers the hole in the handling cave floor when the top of the bin is in the fuel storage area. The bin movement time from one limit to the other is approximately one minute. For maintenance purposes, and to avoid potential contamination problems, the bin drive system is located in the cask transfer pit. In addition to the electric drive motor, the bin drive system is also provided with a hand wheel for manual positioning, should the drive motor fail.

The shuttle bin is designed so that the entire assembly can be remotely disconnected and moved to the crane maintenance area for maintenance. Any time the shuttle bin is to be removed from its pit, the lead shielding plate is first removed from the assembly and suspended from wall brackets so that it totally covers the hole through the shielding wall and maintains the low radiation environment.

The shuttle bin is designed to handle a loaded canister weighing 2000 lb and is designed for an operating lifetime of 10 years, or approximately 3000 cycles.

A drain line connects the bottom of the shuttle bin pit to the cask transfer pit sump, should decontamination of the handling cave and/or the shuttle bin pit become necessary. A manual block valve located in the cask transfer pit will be kept locked open to avoid build-up of water should any water leak into the storage facility.

7.3 Saw

A remotely-operated, variable-speed, continuous band saw (Figure 22), capable of cutting graphite, aluminum, and steel, is provided in the fuel handling cave for decanning the Peach Bottom fuel elements, removing the upper and lower reflector sections from the elements, and cutting the cans and the can inserts to the proper length for disposal.

The saw is mounted on bearing ways attached to the handling cave wall. An electric drive motor can rotate the saw and frame through an arc of approximately 90° to permit positioning the saw over a floor well for fuel cutting and/or against the wall during other cave operations. The frame has a position accuracy of $\pm 1/8$ in.

To use the saw, the item to be cut is clamped vertically in the saw apparatus. The saw blade is then adjusted to the desired cutting elevation with an electric motor jack screw arrangement, the cave vacuum cleaner system (described in the following section) activated, the saw energized, and the item cut. The fuel and scrap pieces are then placed in their respective storage or waste containers. The saw is capable of clamping and cutting tubular

items up to 12-ft long, 6 in. in diameter, and weighing 180 lb. The three clamps used to hold the item being cut are air-opened, spring-closed, and each is capable of supporting 150% of the weight of that section of a Peach Bottom fuel element that it is intended to support. The saw has an electrically-controlled, vertical blade positioning accuracy of $\pm 1/4$ in. The saw also has: (a) a blade-mounted, chromel-alumel temperature sensor that monitors temperature and provides an alarm upon a high sawing temperature; (b) an interlock that prevents saw operation unless the vacuum cleaner system is operating; and (c) a remotely operated CO₂ fire extinguisher head for use in case of fire. For maintenance purposes, the saw blade can be changed remotely, or the saw head can be moved remotely from the cave to the crane maintenance area.

7.4 Vacuum Cleaner

A wall-mounted, remotely-operated, centrifugal vacuum cleaner (Figure 22) is installed in the fuel handling cave to control graphite dust generated during fuel cutting operations and to clean fuel shipping casks and containers prior to returning them to a reactor facility. The vacuum cleaner has two pickup heads, one mounted on the saw in such a manner that the head is always positioned at the cutting operation, and a second attached to a long, flexible hose to permit reaching all areas of the handling cave. The hose system is equipped with a manual, two-way diverter valve to permit independent operation of either head.

The vacuum cleaner system circulates approximately 350 cfm of handling cave air at a minimum velocity in the 4 in. duct of 4,000 ft/min. As the air passes through the vacuum, the dust particles, chips, etc., are collected in a 10 gal, disposable, carbon steel particle-collection container while the air is discharged to the handling cave roughing filter. For shielding purposes, the collection drum is located inside a 2-in.-thick lead pig. The collection container can be remotely removed from the lead pig with the cave manipulator. The vacuum motor can be moved remotely to the crane maintenance area for repair. Interlocks require that the vacuum cleaner be in operation before the saw is energized.

7.5 Cranes

Three cranes are available for use with the Irradiated Fuels Storage Facility: the 15- and 75-ton cranes in the cask receiving area, and the 15-ton crane in the fuel storage facility. In addition, a monorail is located on the storage facility roof.

7.51 Seventy-Five-Ton Crane

An existing 75-ton crane presently serves the CPP-603 cask receiving area. The rails for this crane have been extended into the cask receiving area so that the crane can be used in both cask receiving areas to transfer shipping casks between the transport vehicles and the fuel unloading areas. The new crane rail extension is sized to accept a 160-ton capacity crane which must be installed if the large HTGR cask is to be handled at the IFSF. The 75-ton crane is a Judson-Pacific, with a trolley travel of approximately 27 ft and a hook

Fig 22 Storage facility saw

clearance of 24 ft. A 15-ton crane, manufactured by the Harnischfeger Co., also operates on the same set of rails and thus has the same trolley travel and hook clearance as the 75-ton crane. However, this crane serves only the CPP-603 cask receiving area, and other than operating on the same rails, is completely independent of the 75-ton crane. The heavy duty rails which were installed for a future 160-ton crane are too wide to permit passage of the 15-ton crane.

7.52 Fifteen-Ton Crane

A 15-ton bridge crane has been provided in the fuel storage facility to remove and replace cask lids, load and unload fuel from the casks, and transfer fuel and equipment within the storage facility. The crane has sufficient bridge and trolley travel to permit access to all parts of the storage facility.

The probability of the 15-ton crane completely failing while located in the fuel storage area of the facility is remote. However, personnel access to this area for any reason will be impossible once fuel is present. Therefore, special precautions have been taken in the design of the crane to insure that any probable failure can be corrected. Precautions include a dual bridge drive system, dual electric-hoist brakes, redundant hoist motor drives, a fail-safe, tong-type hook, dual control cables, and emergency power. The crane is also designed to operate in the high-temperature (-200°F), high-radiation environment of the storage facility. However, to prevent unnecessary damage, the crane will be positioned in the crane maintenance area when not in use. Should a total crane failure occur, the crane bridge can be placed in free-wheeling, and the manipulator (Section III 7.6) used to aid in retrieval of the crane. The manipulator will 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 will be used to pull the crane back into the handling cave and crane maintenance area.

As mentioned previously, the crane is provided with a fail-safe tong-type hook. This feature insures that any load will not 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 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 television system is included as an integral part of the crane to provide better visual monitoring of fuel canister handling. A television camera and a 480 V, 1500 W quartz iodide light, are mounted beneath the crane hoist trolley and 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. To ensure a long camera life, the camera is enclosed in a dust- and splash-resistant case.

As a further aid to precise crane positioning^(a), a coordinate position readout system has been provided. The position readout system utilizes synchros driven by the bridge and trolley motions. Through gear reducers, the synchros produce approximately one revolution of the position readout and dials for the entire bridge and trolley travel. The bridge dial indicates the row (1 through 38, with row 1 being farthest from the control room as shown in Fig. 16) over which the bridge is located. The trolley dial indicates the can (A through U) over which the trolley is located. To accurately spot the bridge and trolley at the required coordinate positions, a cam-operated switch is provided for each motion. The switches are operated by adjustable cams installed on the trolley and bridge rails at each coordinate point, i.e., storage canister center. These switches activate a light located above each position readout dial to indicate that the bridge/trolley is exactly on the coordinate position (± 0.125 in.).

7.53 Monorail

A monorail beam with a design capacity of 1,000 lb has been 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 fans, filters, duct, etc.

7.6 Manipulator

A single arm, electrically-operated, remotely-controlled 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 15-ton crane, except no redundant systems other than the trolley drive and control cables are provided. The manipulator specifications are shown in Table VII.

The manipulator is equipped with a 1,000-lb capacity shoulder hook; a 4,000-lb capacity bridge-mounted hoist; wrist, elbow, and shoulder movement; and, an arm reach of about 18 ft, sufficient to retrieve objects from any part of the floor of the handling cave. The manipulator has a capacity of 300 lb with the hand and arm straight down, and 150 lb with the hand and arm in any other position.

The manipulator is fail-safe in that all motions hold their full rated loads with the power off. In addition, a control room key switch, by deenergizing the bridge drive motor clutch, allows the bridge to freewheel and permits using the crane bridge to push the manipulator bridge into the crane maintenance area.

(a) Relatively precise positioning is mandatory to permit inserting and removing fuel storage canisters.

TABLE VII

MANIPULATOR SPECIFICATIONS

Item	Opening	Speed	Force	Torque	Rotation	Travel	Capacity
Hand	0-5 in.	Open-close: 1-18 ipm	0-200 lb	-	-	-	-
Hook	0-6 in.	0.5-5 ipm	0-800 lb	-	-	-	-
Wrist					cw/ccw		
Pivot	-	1.2 rpm	-	-	155°/310°	-	-
Telescope	-	17 ipm	150 lb push/ pull	-	-	4 in. in/ out	-
Rotate	-	1-7 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	4000 lb.
Carriage and Bridge	-	1.5-15 fpm	-	-	-	-	-
Arm (tele- scoping tube)	-	Extend-Retract 1-15 fpm	-	-	-	18 ft	Any posi- tion: 150 lb Verti- cal lift: 300 lb

The crane and manipulator bridges operate on the same set of rails, but are completely independent, thus permitting 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. The manipulator bridge and trolley are supplied with both normal and emergency power so that a loss of normal power will not interrupt manipulator operations.

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.

7.7 Cask Transfer Car

A specially-designed car, located in the cask transfer pit, is used to: (a) support the fuel shipping casks and transfer them between the cask receiving area and the fuel handling cave; (b) isolate the fuel handling cave from the cask transfer pit and maintain ventilation control; and, (c) provide radiation shielding between the fuel handling cave and the cask receiving area. The transfer car, shown in Figure 23, consists of a 12-in.-thick steel plate, 12 ft wide and 35 ft long, mounted on three standard railroad trucks. The car operates on 135-lb Bethlehem steel rails located near the top of the cask transfer pit, and has an overall travel distance of 14 ft. The car is designed and installed so that the fuel handling cave is always isolated from the cask transfer pit, even when the car is in motion.

As discussed in Section II, several different fuel shipping casks are scheduled for receipt at the fuel storage facility. In order 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. Four special plates (one for each shipping cask except the 1100) were also fabricated to adapt the car opening to the casks. When a shipping cask arrives at the storage facility, the proper adapter plate is placed in the transfer car opening and the cask positioned in the plate. With the cask properly positioned in the transfer car, only the top of the cask is exposed to the potentially-contaminated handling cave atmosphere, thus minimizing the decontamination required before the cask can be returned to commercial channels.

Seven steel baffle plates, six fixed and one removable, 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. Four of the fixed baffles are bolted to each end of the car and are enclosed in 1-in.-thick steel plate to form shielding boxes 4 ft 9 in. long, the same thickness as the shielding wall between the fuel handling cave and the cask receiving area. When the transfer car is positioned in either area, a shielding box completely closes the hole in the shielding wall. Each box provides 12 in. of steel for radiation shielding. Both the

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Fig 23 Cask transfer car

shielding boxes and the sides of the transfer car itself are provided with 1-in.-high, 16-gauge stainless steel wipers that maintain continuous contact with the shielding walls to provide building isolation for ventilation control.

The center baffle is a 6-in.-thick steel plate located directly over the center of the hole in the cask transfer car. This baffle is removable to permit positioning car inserts and casks, and is provided to maintain shielding and the proper negative pressure in the handling cave. Tests with each shipment type will determine if it is necessary to use the center baffle.

For decontamination purposes, the upper surface of the cask transfer car, including the center baffle and the inside^(a) edges of the shielding boxes, is clad with 1/8-in.-thick, Type 304 stainless steel. The remainder of the car is painted with radiation-resistant Amercoat paint.

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 both directions, and its position is controllable to $\pm 1/4$ in. Mechanical stops and bumpers capable of stopping the loaded car traveling at maximum speed are provided at both limits of car travel. Operating procedures will require that operators must man both stations before the car is moved.

The cask transfer car is designed for a 10 yr., 2000 cycle lifetime. It is also design to withstand, without damage, an earthquake acceleration of 0.43 g.

7.8 Shielding Door and Movable Crane Rail

An 11-in.-thick, movable steel shielding door shown in Figure 13 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 roundway bearings and tracks located on top of the fuel storage area - fuel handling cave shielding wall. 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 crane maintenance area become reduced radiation zones for limited access, so that personnel entrance into these areas for inspections, preventive maintenance, and equipment repair is possible. When the door is not needed for shielding, i.e., when facility entrance is not required, the door is retracted through the north shielding wall into a storage enclosure.

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 loop is attached to the front edge 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.

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

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 could be serviced with the shielding doors open or closed. As a last resort, if the drive system should completely fail, the doors could 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 min. Limit switches backed up by bumper-snobber devices stop the door when the travel limits are reached. The bumper-snobbers are capable of stopping the door with the door traveling at rated speed.

The shielding door is designed for an operating life of at least 2600 cycles. The door is also designed to withstand without damage an earthquake acceleration of 0.43 g.

Because the shielding door operates perpendicular 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° 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° rotation.

The rail and door are interlocked so that they operate as an integral unit. For example, to actuate the light which indicates "door open" or "door closed" in the facility control room, both the rail and door must actuate their respective limit switches. Open and closed limit switches are provided for both the door and the rail. The switches operate by physical contact, thus insuring positive door and rail positioning. All switches, gears, and drive motors associated with this system are located in either a low radiation zone or in an area that becomes a low radiation zone when the shielding doors are closed.

If the interlock system failed, the interlock circuitry could be bypassed and the doors could be driven closed. If the drive for the rail failed mechanically, the most likely failure would be shearing of a key at the lower end of the shaft which could be replaced from the control room. The gears which actually drive the rail are heavy duty units and the stresses experienced will be lower than those for the keys. The drive motor and shaft are in the control room so the orientation of the rail can be determined visually and it can be determined whether a failure is mechanical or electrical.

7.9 Shielding Windows

Two shielding windows are provided in the storage facility control room walls. One window permits viewing handling cave operations, the other, storage area operations. The windows are lead-glass shielded, oil-filled, approximately 46 in. wide, 49 in. high, and 52 in. thick, and reduce radiation levels at the cold side to less than 0.25 mR/hr from a design radiation level of 50,000 R/hr. The glass used is specified to be nonbrowning after 2×10^8 R of radiation.

The viewing requirements for the handling cave make it necessary to see the floor of the cave at a distance of one foot 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.

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 so that it can 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.

The shield is driven by a control room mounted 1/20-hp electric motor through a driveshaft and worm gear arrangement that penetrates the shielding wall. The motor and limit switches are located on the cold side of the window. If the motor failed or the limit switches malfunctioned, the door could 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 failed, the window could 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.

A flat, stainless steel mirror is also 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.

Both windows are designed so that they can be removed from the control room (cold) side for repair or replacement. The windows are also designed to withstand, without damage, an earthquake acceleration of 0.43 g. 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.

7.10 Hinged Shielding Wall Plug

As discussed in Section III.7.6, the bridge mounted manipulator is capable of complete coverage of the storage facility. However, because the manipulator arm has an extended reach (approximately 18 feet), 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 hinged 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 carbon steel and is approximately 12 in. thick, 24 in. wide, and 50 in. high. When manipulator entrance to the storage area is necessary, the manipulator can be used to engage a lug mounted on the face of the plug. The plug can then be opened by rotating it approximately 110° using a cable and hoist system which has been installed for this purpose. With the plug open, a 30-in. clear opening is provided in the wall through which the manipulator can move. When the plug is in its closed position, two latches are engaged to maintain positive positioning. Positive positioning of the plug is essential since a portion of the shielding door track is attached to the top of the plug. The position can be determined visually through the handling cave viewing window.

7.11 Television System

To aid in initial operator training and to increase visibility during fuel handling operations, a television camera has been mounted on the trolley of the 15-ton crane. The camera is a Diamond Model ST-1, having silicon solid-state components, and enclosed in a dust- and splash-resistant case. The camera is mounted in a fixed position so that coverage is limited to the immediate area where the crane hook engages a storage canister lifting bail. A control room mounted monitor is included as part of the system.

The television camera is not designed to be highly temperature or radiation resistant. Rather, a standard, less-expensive camera has been installed so that should damage occur, a replacement camera can be purchased and installed. However, to prevent unnecessary damage to the camera, administrative procedures require that during periods of nonuse, the crane must be positioned in the crane maintenance area.

7.12 Lighting

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

- a. *Fuel Storage Area:* Eight 480 V, 1000 W, 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 using 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 leakage.
- b. *Fuel Handling Cave:* Ten 480 V, 400 W, 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. The fixtures are recessed into the wall and, to increase illumination, are directed towards the cave floor at an angle of 60°. A wire mesh guard encloses each lamp and protects it from damage. To repair or replace these lights, the cave must be entered.
- c. *Crane Maintenance Area:* Three 480 V, 1000 W, mercury arc lights are installed in the crane maintenance area. This area also contains four duplex wall receptacles. Maintenance of these electrical fixtures requires entrance to the crane maintenance area.
- d. *Crane Trolley:* One 120 V, 1500 W, quartz iodide light is installed on the crane trolley. This light provides approximately 200 candlepower at the storage canisters' lifting bails to provide additional visibility in the immediate area of crane operations,

and illumination for the crane-mounted television 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.

- e. *Control and Instrument Room, Emergency Generator Room, and Shielding Door Enclosure:* The control and instrument room, the emergency generator, and the entry hall between CPP-603 and the facility control room are all provided with standard fluorescent fixtures; the shielding door enclosure contains an incandescent fixture. The control room and the instrument area each contain two 8-ft-long, four-lamp fluorescent fixtures. The emergency generator room and the adjoining hallway contain three 8-ft-long, two-lamp fixtures. The shielding door enclosure contains one 120 V, 150 W incandescent fixture. The control room also contains five 120 V duplex wall receptacles, the emergency generator building two, the hallway and shielding door enclosure one each, and the instrument room five.
- f. *Cask Transfer Pit:* One 120 V, 200 W wall-mounted incandescent light is provided in the cask transfer pit. This light is positioned so that it illuminates the stairway and that portion of the cask transfer pit located in the cask receiving area. A 120 V duplex wall receptacle is also located in the cask transfer pit to permit the use of extension cords should additional lights or power tools be required in this area.
- g. *Cask Receiving Area:* Six 1000 W and two 400 W mercury arc lights illuminate the cask receiving area. Three additional 175 W mercury arc lights are located outside the cask receiving area above the rollup doors, and illuminate the truck ramp and the railroad spur. Two 120 V duplex wall receptacles are also located in this area.
- h. *Emergency Lights:* 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 emergency power system. Upon a loss of normal power, these lights are automatically switched to the emergency generator system. Mercury arc lamps, however, require a warm-up time of approximately 10 min. Thus, when power switches from either normal to emergency or from emergency to normal, all mercury arc lamps are off for about 10 min. To provide adequate lighting during these time periods, three 200 W incandescent lights are installed in the three areas mentioned earlier. These lights are connected to the emergency power system through a timer so that they operate for about ten minutes each time power switches from one system to the other. Ten minutes provides enough time for the mercury lamps to warm up and begin operating. The duplex wall receptacles are also connected to the emergency power system.

8. UTILITIES

As far as possible, utilities for the storage facility were obtained by connecting to existing CPP-603 utility systems.

8.1 Water

Water for the fuel storage facility was obtained from the 10-in. diameter fire water line that supplies raw water at approximately 80 psig to CPP-603. Water is provided to the crane maintenance area decontamination pad for equipment decontamination purposes, the cask receiving area for removing road dust from casks and trucks and decontaminating empty casks, a safety shower in the access hallway between CPP-603 and the facility control room, and the emergency generator for cooling. Drinking water and sanitary facilities are both located in building CPP-603.

8.2 Fire Water

Fire protection for the entire ICPP area is provided by a fire water distribution system that supplies the fire hydrants throughout the ICPP plant area. Water pressure within the system is normally maintained at approximately 80 psig by the raw water pumps. Should the fire water system pressure decrease to 60 psig, automatic switchgear would start the emergency electric fire water pump. The emergency pump is a centrifugal pump driven by a 200-hp motor, and delivers 2,000 gpm at 78 psig. The switchgear for this pump is located in the service building (CPP-606). The electric fire water pump is backed up by a diesel fire water pump that delivers 2,000 gpm at 86 psig, and is driven by twin diesel engines, each rated at 194 hp. Fuel for the diesel engines is supplied from a 1,000-gallon steel storage vessel. Both the electric and diesel fire water pumps are test-operated weekly to insure their readiness.

8.3 Electrical

Normal electrical power (120 and 480 V) for the storage facility is obtained from building CPP-603. Sufficient power is available at CPP-603 to supply both the existing and the new equipment. The facility is also supplied with 110 V receptacles, and welder and telephone outlets in sufficient quantity to conform to the National Electrical Code and general site practice.

Emergency electrical power is obtained from the 115 kW, propane fueled, 440 V, 3 ϕ emergency generator installed in the reinforced concrete building located at the northeast corner of the storage facility as shown in Figure 12. Upon a 5-sec loss of normal power, the emergency generator starts automatically and, after a 3-min delay to allow the generator to reach operating speed, assumes the required load. When normal electrical power is restored, the transfer switch, after a 5-sec delay, automatically transfers the operating equipment back to normal power and, after another 2 min, shuts down the emergency generator. A 440 V, 3 ϕ motor control center is installed on the northeast wall of the storage facility to house the control devices required to start the emergency generator, perform the switching functions, and house the breaker boxes. The total connected load, if all motors were operating at full rated capacity and the breakers supplying the standby panel and the lighting panel were at their respective trip points, would be approximately 127 kW, which would exceed the rated capacity of the emergency generator. However, if the normal

number of fans were operating, the load would be approximately 88 kW, which is well within the rated capacity of the generator. The emergency generator will be test-operated monthly to insure operational readiness.

All 110 and 220 V outlets and lights in the storage facility are connected to the emergency power system. In addition, the following equipment is also connected to this system.

a. *Cask Transfer Car*

As designed, the cask transfer car may be stopped at any intermediate position without unbalancing or disrupting the heating and ventilating systems, causing a radiation problem, or seriously affecting the storage facility. However, the most desirable position for the transfer car is either in or out of the facility, not inadvertently stopped in an intermediate position. Therefore, to insure a continuous source of electrical power and provide this capability, the transfer car drive motor is connected to the emergency power system.

b. *Heating and Ventilating Fans*

A significant amount of decay heat is associated with the stored fuel, and although a brief interruption would not be serious, continuous cooling should be maintained. To insure a continuous supply of cooling air and avoid excessive fuel temperatures, all heating and ventilating fans except the 14,000 cfm supply fan and the 12,000 cfm exhaust fan are connected to the emergency power bus. Should normal electrical power be lost, the emergency generator would supply power to the standby fans which would start automatically. These fans are capable of (a) supplying cooling air flow through the storage area, and (b) maintaining the cave at an approximate pressure of minus 1/8-in. of water. In addition, backup fans also capable of providing 7000 cfm of cooling air flow will start automatically if the standby fans fail. Both standby and backup fans can be operated simultaneously to provide flow equal to the normal 14,000 cfm if desired, but this is not necessary to maintain safe fuel temperatures.

c. *Crane and Manipulator*

Except in an emergency, all operations in the fuel storage area and the cave are performed with the crane and manipulator aided by the television system and the crane-mounted light. The crane and manipulator and their associated systems (except the TV camera) are all designed to withstand the high radiation levels expected in the fuel storage area. Radiation does, however, shorten the life of many crane and manipulator components, and unnecessary radiation exposure is not desirable. In addition, being able to complete an "in progress" operation requiring the crane or manipulator is also desirable. Therefore, both of these units are connected to the emergency power system.

d. *Lights*

Sufficient lights throughout the fuel storage facility are supplied with emergency power to insure any operation can either be safely completed or terminated.

e. *Health Physics Instruments*

Safe operation of the storage facility requires sufficient radiation instruments to provide a complete and continuous knowledge of the radiation levels in and around the storage facility. Therefore, two constant air monitors, a remote area monitoring system, and a facility stack monitor are provided to detect and record radiation levels and are connected to the emergency power system. Through these instruments, operating personnel are provided with a continuous knowledge of the radiation levels in the facility.

8.4 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 storage facility, the steam is used only in the crane maintenance area at the decontamination pad for decontaminating equipment, and in the cask receiving area and the control room for heating (temperature control). Steam is also available at the CPP-603 decontamination pad for use in cask decontamination work.

8.5 Air

Plant and instrument air are obtained from the 90 psig, 40 cfm, Gardner-Denver air compressor that supplies air to CPP-603. Air is available at several areas in the facility, 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, saw clamps, and maintenance and decontamination work.

Breathing air will be obtained from self-contained breathing apparatus for emergency use and from a portable breathing air compressor for longer-term use.

8.6 Heating and Ventilation

A heating and ventilating system shown schematically in Figure 24, is provided in the fuel storage facility to (a) remove the decay heat^(a) generated by the stored fuel, (b) provide ventilation for the facility, (c) maintain facility areas at desired positive and negative pressures, and (d) maintain an air-flow pattern within the facility that is always from a less contaminated to a more contaminated region. The H & V system maintains the entire storage facility (except the control room) at a negative pressure of 1/8-in. of water, and at a temperature less than 200°F. The control room is at a positive pressure of 1/8-in. of water. The air flow is shown in Figures 20 and 25.

(a) Calculated to be 1.2×10^6 Btu/hr for a full facility. See Appendix A.

Fig. 24 Schematic of heating and ventilation system.

Fig. 25 Cooling air system.

The basic criteria for the heating and ventilating system are that it cool the stored fuel and prevent the spread of radioactive contamination. In order to achieve these criteria, the heating and ventilating system consists of three subsystems: one serving the control room and crane maintenance area; one serving the fuel storage area and the fuel handling cave; and one serving the cask receiving area. Each subsystem is described in the following paragraphs.

8.61 Control Room and Crane Maintenance Area

The control room is supplied with 1,000 cfm of filtered, tempered air. The system maintains the control room at a temperature of approximately 70°F, and a positive pressure of $\sim 1/8$ in. of water so that any leakage will be out. After exiting the control room, the ventilation air passes through the crane maintenance area, the handling cave, and the handling cave roughing filter before being discharged to the atmosphere through prefilters, HEPA filters, an exhaust fan, and the facility stack.

8.62 Fuel Storage Area and Fuel Handling Cave

Filtered atmospheric air is directed through the fuel storage area and the fuel handling cave by a combination of supply and exhaust fans. The cooling air enters the storage area in two streams, one that contains 85% of the air and flows through the storage rack, and a second that contains 15% of the air and flows above the storage rack.

That part of the air that flows through the storage rack (as shown in Fig. 25) enters the rack through a distribution plenum located at the west end of the rack. The plenum contains 18 openings (as shown in Figs. 18 and 20), each 20 in. long and 12 in. high, that distribute the air uniformly across the rack to insure adequate cooling for each storage canister. After passing through the rack, the air exhausts through eight openings in the bottom of the discharge end of the rack and is then collected in an exit plenum at the east end of the rack. The air then passes through prefilters, HEPA filters, and exhaust fans before being discharged to the atmosphere through a stack, the top of which is 65 ft. above grade. The inlet and exhaust opening doors will be adjusted for uniform air flow, then welded in place. This will insure uniform distribution of cooling air across the rack. The seven storage rack positions which are 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 will provide adequate cooling to these few positions if it becomes necessary to use them. However, during the initial stages of use of the facility, all of rows 36, 37 and 38 (24 positions) will be designated as spare positions. The storage positions designated for use in the early stages of operation form a rectangular, squared-off region which will make location of the proper position easier and more reliable. After more experience is gained on temperatures experienced in the rack, it may be desirable to use these positions for active storage. The use of these 24 positions will be evaluated at that time.

The air that enters above the storage rack cools that portion of the storage facility located above the top of the rack and prevents hot spots. This air enters the facility 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 to enter the fuel handling cave and combine with the 1,000 cfm entering the cave from the crane maintenance area and the approximately 2,000 cfm that infiltrates the storage facility. The cave exhaust air (5,000 cfm) passes through the handling cave roughing filters before being discharged to the atmosphere through prefilters, HEPA filters, and the stack.

8.63 Cask Receiving Area

The cask receiving area is heated and ventilated by four unit heaters supplied with steam, identical to those used in the CPP-603 building. The heaters are arranged so that the temperature of the receiving area can be controlled uniformly at approximately 68°F. Condensate from the unit heaters is discharged to the CPP-603 cold drain system.

8.64 Fans

The heating and ventilating system contains nine fans: four supply and five exhaust. All the fans except two are supplied with normal and emergency power so that a complete loss of facility cooling air is extremely remote. The number, size, horsepower, and power sources of each fan are shown in Table VIII.

TABLE VIII
HEATING AND VENTILATING SYSTEM FANS

<u>Fan</u>	<u>Number</u>	<u>Size (cfm)</u>	<u>HP</u>	<u>Power Source</u>
Control Room Supply	1	1,000	1.5	Normal and Emergency
Storage Area Supply	2	7,000	7.5	Normal and Emergency
	1	14,000	10.0	Normal
Storage Area Exhaust	2	6,000	15.0	Normal and Emergency
	1	12,000	30.0	Normal
Handling Cave Exhaust	2	5,000	15.0	Normal and Emergency

During normal facility operation, the fans operate as follows: one set of storage area fans (one supply fan and one exhaust fan) is in operation, one set is on standby, and one set is for backup. The control room supply fan is in operation, and one of the cave exhaust fans is operating with the other on standby. Thus, should either a mechanical or electrical failure occur, redundant air supply systems are available and will start automatically to provide cooling air.

The only operating restrictions for the heating and ventilating system are: (a) the operating supply and exhaust fans be balanced, i.e., the supply and exhaust air streams be of equal volume; and (b) an exhaust fan be placed in operation before a supply fan so that the facility is always under a negative pressure. As explained in Section IV, the heating and ventilating control system automatically meets both of these requirements.

The ventilation system is designed to maintain the fuel storage facility, except the control room, at a negative pressure of $\sim 1/8$ in. of water, and the fuel storage area at a temperature less than 200°F. The control room will be maintained at a positive pressure of $\sim 1/8$ in. of water.

The facility pressures are maintained by balancing dampers located in each supply and exhaust duct. The dampers are manually set to maintain pressure at a predetermined value. If necessary, the balancing dampers can be manually placed in the fully open position.

Each supply and exhaust duct also contains a backdraft damper to prevent formation of closed flow loops through adjacent fans. A backdraft damper operates in conjunction with a supply and exhaust fan. Any time a fan is started, the backdraft damper associated with that fan also opens. If an operating fan loses power, the backdraft damper closes. If necessary, 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.

Nonoperating fans will be test-operated monthly to insure their operational readiness.

8.65 Filters

Roughing filters, prefilters, and HEPA filters remove particulates from the storage facility cooling air streams. The inlet air streams pass through roughing filters to remove dust and foreign material before entering the facility. The exhaust air streams pass through both prefilters and HEPA filters to remove dust and foreign material before being discharged to the atmosphere. The prefilters and HEPA filters are enclosed in housings (caissons).

The roughing filters and the prefilters are 60% efficient when tested by the NBS Atmospheric Dust Spot Test. The HEPA filters have an efficiency of 99.97% for particles 0.3 micron in diameter as tested with dioctyl phthalate (DOP) smoke. The prefilters are constructed of fire-resistant components and are designed to withstand a temperature of 250°F. All the facility filters are replaceable without posing a radiation hazard to maintenance personnel. The cave roughing filter, the exhaust air prefilters, and the HEPA filters are instrumented with Magnahelic pressure gauges 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. Periodic radiation surveys will determine whether a change based on radiation level is necessary. The filter caissons are provided with upstream and downstream taps for in-place DOP smoke testing. An initial test has been satisfactorily performed and the system will be placed on the normal annual retesting schedule for all ICPP HEPA filters.

8.66 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 stack is approximately 65 ft above grade. The discharge air is checked for activity by a stack monitor.

9. WASTE DISPOSAL

During normal operations, gaseous, liquid, and solid wastes are generated at the fuel storage facility. Where possible, these products are disposed of through existing methods, systems, and equipment. In certain cases, new disposal systems were installed. Regardless of the method or system used, however, all wastes are disposed of according to established guidelines and any activity released to the environment would be well below guideline levels (see Section VI.3.).

9.1 Gaseous

The storage facility cooling system continuously forces about 14,000 cfm of air through the storage area to maintain the centerline temperature of the hottest fuel elements at a relatively low level, approximately 365°F. If the facility is filled with fuel, the heat load is approximately 1.25×10^6 Btu/hr, resulting in a cooling air exit temperature of 175°F. This decay heat load is roughly equivalent to that of the PIF office building (CPP-637) and is insignificant in the INEL environment.

The temperature of the stored fuel (365°F) is well below the fission product migration temperature (1000°F, Section VI.3) for graphite fuel, and neither particulate matter nor fission gases will be released to the fuel canister as a direct result of temperature. Should gases or particulate matter be released from the fuel by some unknown method, the closed storage canisters would help retard their entering the cooling air stream. Furthermore, before being discharged to the atmosphere through the stack, the cooling air passes through prefilters and HEPA filters where essentially all particulate is removed. Thus, for these reasons, no significant amount of radioactive gases or particulate matter will be released to the environment.

9.2 Liquid

Liquid wastes will be generated at the fuel storage facility during equipment and facility activities. Although remote, the possibility exists that at times the wastes might be slightly contaminated. Therefore, all liquid waste streams generated at the 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 VES-SFE-20, the hot waste catch tank located just east of CPP-603. From VES-SFE-20, the wastes are pumped to the CPP-604 evaporator for concentration, and eventual calcination and storage.

All nonradioactive liquid wastes, primarily condensate from the cask receiving area and the control room space heaters, also flow to an existing CPP-603 disposal system—the uncontaminated waste system. This system collects all uncontaminated waste generated in the CPP-603 area and routes them to the waste disposal pit located about 200 ft north of the storage facility.

9.3 Solid

Solid wastes are produced at the storage facility when the Peach Bottom fuel elements are prepared for storage. These wastes consist primarily of aluminum storage cans, steel liners, and graphite reflector pieces. Radiation measurements of irradiated Peach Bottom fuel elements performed by Gulf General Atomic indicated that the probable radiation levels that will be encountered with the Peach Bottom waste products are approximately as shown in Table IX.

TABLE IX
RADIATION LEVELS OF PEACH BOTTOM SOLID WASTES

<u>Item</u>	<u>Radiation (R/hr)</u>	<u>Distance (in.)</u>
Aluminum Storage Can	None	Contact
Graphite Sleeve (stored with fuel)	8 to 17	Contact
Upper Reflector	0.007	Contact
Lower Reflector	0.35	2
Charcoal from Fission Product Trap	0.15	2

Based on the information in Table IX and the INEL waste disposal criteria, the solids wastes will be disposed of as outlined in the following subsections.

9.31 Graphite Reflector Sections

The upper and lower reflector sections from the Peach Bottom fuel elements will be disposed of as hot waste. As the reflector pieces are removed from the fuel elements, they will be placed in disposable cask inserts that fit in the Waste Calcining Facility (WCF) filter cask (Figure 26). When the cask insert is full (about 100 reflector pieces) the insert will be placed in the WCF filter cask and taken to the INEL Radioactive Waste Management Complex (RWMC).

9.32 Steel Liners

A steel liner was inserted in each Peach Bottom spent fuel can to provide reactivity control in the reactor spent fuel storage basin and to insure nonbuoyancy of the cans. These inserts are an integral part of the cans and will also be handled as hot waste. Thus, the liners will be disposed of with the cans at the RWMC.

Fig 26 Solid waste disposal (WCF filter) cask with insert

9.33 Aluminum Cans

The aluminum cans are not radioactive and will probably be only slightly contaminated. However, when empty, the cans will be disposed of as solid waste, in a manner similar to the graphite reflector pieces and the steel liners. A basket similar to the Peach Bottom basket will be used to transfer the uncut cans with their steel liners to the RWMC. The basket will be retained for use in disposal of the remaining reflector sections if further cutting of Peach Bottom fuel is necessary at a later date.

9.34 Filters

Prefilters and HEPA filters are installed in the storage facility's cooling air discharge streams to remove particulate matter. The filters are in caisson-type enclosures and permit "bagging-out" individual filters. Contamination of the filters is highly unlikely, but is possible. Therefore, as each filter is removed, it will be checked for contamination and will then, depending upon the results of the check, be disposed of as hot or cold waste.

9.35 Miscellaneous

Miscellaneous wastes—tops from aluminum storage cans, graphite dust, metal filings, vacuum cleaner filters - will be disposed of as contaminated waste. Cask inserts and the WCF filter cask will be used to contain and transport these wastes.

IV. INSTRUMENTATION AND CONTROL SYSTEMS

The Irradiated Fuels Storage Facility is provided with sufficient instruments, control systems, and alarms to insure the proper and safe operation of the facility. In most cases, both the instruments and the control systems are located in the facility control room. This section describes the instruments and controls provided in the storage facility, as well as the control circuits associated with these systems. A summary of the facility instrumentation is presented in Table X.

1. PROCESS INSTRUMENTATION

The process instruments associated with the fuel storage facility consist primarily of indicators, recorders, and position indicating lights. Each is discussed below.

1.1 Filter Differential Pressure

Each of the six prefilter banks, and the six HEPA filter banks, and the handling cave roughing filter is provided with a Magnehelic differential pressure indicator. These devices sense the differential pressure that exists across each filter bank and provide a continuous control room indication of these pressures. The roughing filter and the prefilter Magnehelics have a range from 0 to 2 in. of water. The HEPA Magnehelics have a range from 0 to 4 in. of water. Initial differential pressures for new roughing and prefilters is 0.26 in. of water; for HEPA filters, 1 in. of water.

1.2 Facility Differential Pressure

The differential pressures that exist between the atmosphere and the storage area, and the atmosphere and the control room, are indicated on two photohelic gauges mounted in the facility control room. These instruments have a range from -1 to +1 in. of water, and have a variable setpoint that provides a control room alarm upon a change in pressure. The heating and ventilating system is designed to maintain the storage area at an approximate negative 1/8 in. of water and the control room at an approximate positive 1/8 in. of water.

1.3 Cooling Air Flow

Two flow transducers are provided in the storage facility exhaust air streams, one in the storage area exhaust and one in the handling cave exhaust. Each transducer provides a signal to a flow computer which, in turn, provides a signal to a two pen control-room-mounted recorder. One pen, with a range to 30,000 cfm, records storage area flow; the other, with a range to 15,000 cfm records cave flow. Each pen actuates an alarm upon a low flow. Total stack flow may be obtained by adding the two flow signals.

1.4 Cooling Air Temperatures

Thermocouples are located in the cooling air inlet plenum, the cooling air exit plenum, and the stack, to continuously monitor temperatures of the inlet and exit air

TABLE X

INSTRUMENT SUMMARY

Instrument	Service	Control Point	Expected Operating Range	Instrument Range	Alarm Point High	Low
<u>Saw</u>						
1. Temperature sensor		None	70-200°F	0-1500°F	None	None
2. Position indicator		±1/4 in.	0-12 ft vertical; 90° arc	Same as operating range	None	None
3. Vacuum: On-Off		None	Vacuum must be operating before the saw can be placed in operation.			
<u>Ventilating</u>						
1. Control switches		On-Off	-	-	-	-
2. Filter ΔP						
a. Roughing filter		None	0.25-1 in. of water	0-2 in. of water	None	None
b. Prefilters		None	0.25-1 in. of water	0-2 in. of water	None	None
c. HEPA filters		None	1-3 in. of water	0-4 in. of water	None	None
3. Facility ΔP						
a. Control room to atmosphere		~+1/8 in. of water	>+1/8 in. of water	-1-+1 in. of water	None	+1/8 in. of water
b. Fuel storage area to atmosphere		~1/8 in. of water	<-1/8 in. of water	-1-+1 in. of water	-1/8 in. of water	None
4. Supply air temperature		None	-40-100°F	-	None	None
5. Exhaust air temperature		None	50-200°F	-	200°F	None
6. Facility Flow						
a. Storage area		-	0-14,000 cfm	0-30,000 cfm	None	6,000 cfm
b. Fuel Handling Cave		-	0-5,000 cfm	0-15,000 cfm	None	4,000 cfm
7. Stack Monitor		None	-	0-10 ⁵ counts/min	10 ⁴ counts/min	None
<u>Emergency Generator</u>		None	-	-	Provide control room alarm upon emergency generator operation	
<u>Operating Indication</u>						
<u>Area Radiation Monitor</u>		-	-	0-001 to 10,000 R/hr	7.5 mR/hr	None (areas occupied by personnel)

streams. Except for the stack, these temperatures are read-out on a multipoint temperature sensimeter located in the facility control room. Through pushbuttons, this instrument permits selection and digital readout of any desired thermocouple. The stack gas temperature is continuously indicated on an instrument located in the facility control room. This instrument has a range of 0 to 300°F, and provides an alarm upon a high temperature.

1.5 Storage Area Temperature

Nine chromel-alumel thermocouples are located in the fuel storage area to continuously monitor surface temperatures of the north and south walls, and the storage rack. These thermocouples are also connected to the multipoint temperature sensimeter located in the facility control room. In case of thermocouple failure it is possible to replace the failed TC from outside the storage area building.

1.6 Indicating Lights

Lights of various colors that indicate the operating condition and position of several pieces of storage facility equipment are provided in the control room. Green indicates an operating (run) condition; yellow abnormal; and red stop. Blue lights indicate equipment positions.

2. RADIATION MONITORING EQUIPMENT

Concrete, steel, and lead shielding walls, and shielding windows are provided in the storage facility to protect personnel from the direct radiation associated with the stored fuel. Additional protection is provided by radiation detecting and indicating instruments, including constant air monitors, remote area monitors, friskers, and hand and foot counters. These instruments provide alarms upon detecting a high-radiation level. Instrumentation is also provided to detect activity in the cooling air stream being discharged from the facility.

2.1 Constant Air Monitors

Constant Air Monitors (CAM's) detect airborne radioactive contamination (β , γ) by continuously sampling the air in a given area and provide both audible and visual alarms (bells and lights).

If desired, a hose may be attached to a CAM so that air samples (to 5 cfm) can be drawn from remote areas of a facility. CAM's are installed in the instrumentation room and the cask receiving area of the storage facility to provide continuous surveillance of those areas where personnel are permitted unlimited access. A sampling tube is provided between the control room CAM and the crane maintenance area so that whenever access to the crane maintenance area is required, this CAM can provide the necessary surveillance. In addition to the instrument mounted alarm, each CAM is provided with a control room recorder. These recorders actuate an annunciator upon detecting a high activity level.

2.2 Remote Area Monitors

A remote area monitoring (RAM) system is provided in the fuel storage facility to indicate direct radiation levels within the facility and to alert operating personnel to potential radiation hazards. The RAM system consists of nine radiation detectors located in selected areas of the facility. The detectors provide a signal to control room mounted instruments so that continuous indications of the facility radiation level are available. Each control room indicator can activate a control room annunciator upon a high facility radiation level. The alarms are also reset in the facility control room. The location and range of the remote detector heads are shown in Table XI. The detecting head located in the handling cave is installed so that it can be remotely removed for maintenance. The RAM system will be used in lieu of a specific criticality monitor. This system does not meet the requirements of ANSI Standard N16.2 but should provide information on whether a criticality has occurred. AECM 0530 Part II Nuclear Safety, par. 3. c, p 6, covering criticality monitoring systems, states "This paragraph is not intended to require underwater monitoring when special nuclear material is handled or stored beneath water shielding adequate to protect the personnel". The IFSF does not use water for shielding, but the areas where a criticality could conceivably occur are shielded to protect personnel from direct radiation from the irradiated fuel and consequently from a criticality. For this reason, no specific criticality monitors are provided.

2.3 Nuclear Accident Dosimeters

Nuclear Accident Dosimeters (NAD's) will be placed in the control room and the handling cave. In the unlikely situation that a criticality should occur, the NAD's will be examined to determine the magnitude of the criticality and the resulting doses to the operating areas.

2.4 Friskers

Friskers are not used at the IFSF at the present time because of the high background radiation levels from the adjacent basin area.

2.5 Hand and Foot Counter

A hand and foot counter, an instrument specifically designed for checking contamination on an individual's hands and feet (the most common parts of the body to become contaminated), is located in the cask receiving area. This instrument detects and indicates the contamination present on each hand and each foot, and provides both an audible and a visual alarm if contamination levels exceed preset values.

2.6 Self-Monitor

A self-monitor consists of a portable GM survey meter with an audible alarm and is used by an individual to survey himself for contamination. A self-monitor is provided at the

TABLE XI

RAM SYSTEMS DETECTORS - LOCATIONS AND RANGES

<u>Detector</u>	<u>Location</u>	<u>Range (R/hr)</u>
1	North wall of cask receiving area at cask transfer pit	0.001 to 10
2	North wall of cask receiving area at cask unloading point	0.001 to 10
3	Cask transfer pit at shuttle bin mechanism	0.001 to 10
4	Northwest corner of crane maintenance area at entrance door	0.001 to 100
5	West wall of crane maintenance area in labyrinth	0.01 to 1000
6	South wall of control room at shielding window	0.01 to 1000
7	West wall of control room at shielding window	0.1 to 10,000
8	South wall of emergency generator room at crane maintenance area entrance door	0.001 to 10
9(a)	North wall of fuel handling cave at shielding window	0.1 to 10,000
10	Spare	

(a) Remotely removable for maintenance.

storage facility in the area just outside the crane maintenance area door^(a) so persons leaving the crane maintenance area may check themselves for contamination.

2.7 Stack Gas Sampler and Monitor

Radioactivity discharged to the storage facility stack by the cooling air stream is detected, measured, and recorded by the stack gas sampling and monitoring system. This system continuously draws a 0.5 to 1.0 cfm air sample from the stack gas stream, passes the sample through the stack gas sampling system (CAM), and then returns the sample to the stack. The activity of the sample stream, and thus the stack gas, is determined by passing the sample stream through a high-efficiency filter and continuously measuring the activity of the filter with a scintillation detector connected to a recorder and an alarm. Periodically, the filter is changed and analyzed to identify the collected radioactive solids. The stack gas sampling system also provides taps for obtaining "grab" samples of the stack gas.

2.8 Protective Clothing

Protective clothing is provided to all persons directly engaged in work involving radioactive material. The clothing is clearly marked, and is for use only in areas where contamination may be present. A supply of the required clothing and equipment is maintained at the fuel storage facility in the area between the crane maintenance area door and the emergency generator room, and consists of shoe covers, coveralls, lab coats, gloves, head coverings, and respiratory devices (face masks, respirators, and self-contained air supply units). The amount and type of protective and safety clothing and equipment required by an individual entering the storage facility is dictated by each individual case. Generally, the requirements depend upon the work to be performed and the conditions existing at the time the work is to be performed. Health Physics personnel are responsible for providing and maintaining the protective clothing and equipment, and for specifying the clothing to be worn for each particular job.

2.9 Health Physics Support

In addition to the instruments and equipment previously described, supplementary radiation detection instruments are also available at all times. These instruments include high-volume air samplers, portable radiation detection instruments and a smear counter to aid in detecting contamination and permitting precautions to be taken to prevent its spread.

Health Physics coverage within the ICPP is provided on a 24-hr-a-day basis; coverage for the IFSF is provided on an "as necessary" basis, i.e., Health Physicists are available when operating conditions require their presence, for instance, when transferring a cask to or from the facility.

(a) This area is the access hallway between the Irradiated Fuels Storage Facility and CPP-603.

3. CONTROLS AND CIRCUITRY

The controls and circuitry for the fuel storage facility equipment and systems are located in the facility control and instrument rooms, and include those for the crane, manipulator, cask transfer car, movable shielding door, fuel shuttle bin, saw and vacuum cleaner, and heating and ventilating. The following sections briefly describe these systems.

3.1 Crane

Power to the 15-ton crane 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 only provides power to redundant systems, i.e., bridge and hoist drives. The system in use is selected by a switch located on the crane power center door. The crane is powered from both the normal and emergency systems. In the event of a loss of normal power, the emergency system automatically provides power.

The crane may be controlled from either a control room station or from a control pendant in the crane maintenance area. Both stations permit complete operation of the crane, and both can be plugged in at the same time. 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 in the junction box to pass control to the control room unit. Each station is provided with a light to indicate control rests with that station. In addition, each control station plug is color coded to prevent confusion.

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

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

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

Disconnecting main power to the crane allows the bridge to freewheel and permits bridge retrieval by the crane retrieval system. As long as the main breaker is closed, however, the bridge clutch remains engaged, even without a controller on, thus preventing undesired bridge freewheeling.

The crane trolley and bridge are equipped with a position indicating system, previously described in Section III, 7.5.

3.2 Manipulator

The manipulator control system is quite similar to that provided for the crane. That is, 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 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 during a loss of power all motions hold their full-rated load, 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 with the crane 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 not provided with emergency power.

3.3 Cask Transfer Car

The cask transfer car can be controlled from two locations: the facility control room or the cask receiving area. 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 keyswitch 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 emergency power.

3.4 Movable Shielding Door

The three-sectioned, steel shielding door and the motorized section of the north crane rail operate as an integral unit. That is, if the door is open and the close button is pushed, the swinging rail must open before the door can close and vice versa. The control station for the door and rail is located in the facility control room and includes lockout switches at the rail and door motors, and a key-operated master lockout switch on the control panel. The system also includes limit switches to prevent rail and door overtravel and blue indicating lights to show door position. A green light is illuminated any time the rail or door is in operation. The lockout switches are provided for safety reasons, and prevent operation of this system when maintenance work is being performed on either unit. 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, thus insuring positive movement. The shielding door is provided with normal power only.

3.5 Fuel Shuttle Bin

The shuttle bin control panel is located in the facility control room and consists of 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; limit switches to prevent bin overtravel; a key-operated travel limit switch bypass; and blue position indicating lights. The key-operated lockout switch prevents inadvertent or unauthorized operation of the bin. The limit switch bypass permits movement of the bin into the fuel handling cave beyond its normal limit for maintenance purposes. The shuttle bin is provided with normal power only.

3.6 Saw and Vacuum Cleaner

The saw and vacuum cleaner operate as a unit. That is, the vacuum cleaner must be operating before the saw can be placed in operation. Controls for the vacuum system include an on-off switch and red, yellow, and green operating condition lights. A green light indicates a normal operating condition, yellow abnormal, and red nonoperating. If the vacuum is turned on and is not operating within 10 sec, an alarm is received and the yellow abnormal operation light illuminates.

The saw controls also include an on-off switch and operating condition lights. In addition, the following functions are controlled from this panel.

a. *Clamps.* A clamp open-close switch is provided for each of the three saw clamps. These switches operate solenoid switches that direct air to the clamps to open them, or vent air from the clamps to allow springs to close them.

b. *Frame.* A three-position (forward, off, reverse) switch controls the electric motor that rotates the saw frame through an arc of approximately 90°. The frame travel time is approximately two min with a positioning accuracy of $\pm 1/4$ in.

c. *Height.* A three-position (raise, off, lower) switch controls a totally-enclosed electric motor jack screw arrangement that raises and lowers the saw so cuts can be made at different elevations. The saw moves through a total vertical distance of 12 ft with a location accuracy of $\pm 1/4$ in.

d. *Cutting Tension.* An open-cut switch actuates the constant feed device that regulates the saw blade pressure. This device also rotates the saw away from the cutting area so that items can be inserted and removed from the clamps.

e. *Cutting Speed.* A potentiometer serves as a variable speed controller to regulate the saw blade speed from 60 to 3,000 ft/min. The speed at which the blade is set will depend, of course, upon the material being cut.

f. *Cutting Temperature.* A chromel-alumel thermocouple mounted at the saw blade continuously monitors the blade (cutting) temperature. A control panel mounted pyrometer provides the operator with a continuous indication of the cutting temperature. The pyrometer has a range of 0 to 1,500°F.

3.7 Ventilation System

The ventilation and cooling air is supplied 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 control systems for these ventilation systems are essentially identical to each other and consist of the following: key-operated manual-start switches; lockout switches for maintenance activities; selection switches for standby operations; air switches and interlocks to isolate failed systems and start standby systems; and red, yellow, and green operating lights to indicate stop, abnormal, and run, respectively.

The ventilation system is designed so that the 14,000 cfm supply unit and the 12,000 cfm exhaust unit, which make up System 2 act as the normally operating system. Systems 3 and 4, each made up of one 7,000 cfm supply unit and one 6,000 cfm exhaust unit act as the first and second standby system. That is, if System 2 fails, System 3 automatically starts; and if System 3 fails, System 4 automatically starts. System 2 cannot serve as an automatic standby, only a manual backup, if for some reason System 3 or 4 are being operated as the normal. Under normal circumstances, only one set of standby blowers will start, providing 7,000 cfm of cooling air. With a full facility, this will yield a calculated fuel centerline temperature of approximately 550°F and an exit air temperature approximately 25°F higher than that for 14,000 cfm. Therefore, 7,000 cfm is satisfactory for long term storage. In fact, only 10% of normal flow provides a safe fuel centerline temperature indefinitely. If desired, the second set of standby blowers may be manually started, providing 14,000 cfm of cooling air.

For control purposes, supply and exhaust fans must be operated as a system, i.e., in prearranged pairs. In addition, the exhaust fan must be started before the supply fan, and a 5,000 cfm cave exhaust fan (System 1) must be in operation before the other systems can be placed in operation^(a). The control system automatically fulfills all these requirements.

If a ventilation system is placed in operation, the exhaust fan starts immediately; the supply fan starts after a 10-sec delay. If for any reason either fan fails to start or an operating fan fails, the other fan in the selected system automatically stops and the standby system starts.

As mentioned, any of the three primary ventilation systems can be the operating or the backup system. However, only Systems 3 and 4 can be the automatic standby units. The cave exhaust system consists of two 5,000 cfm exhaust fans, either of which can be the operating unit. As soon as one unit is selected as the operating unit, the other automatically becomes a standby unit. The 1,000-cfm control room supply fan (System 5) does not have a standby or backup fan since total failure of this portion of the ventilation system will not adversely affect the stored fuel.

(a) This requirement can be bypassed through the use of the bypass key switch.

All the ventilation systems, except System 2, are supplied by both normal and emergency power. Thus, upon a loss of normal power, any operating system except 2 will continue to operate. If System 2 is operating at the time of a power failure, either System 3 or System 4, depending upon the one selected, will start to take the place of System 2.

A control room alarm is provided for each ventilation system to indicate a system failure.

4. ANNUNCIATOR SYSTEM

An annunciator system is installed in the storage facility control room to provide alarms and alert operating personnel to an abnormal condition that should be corrected. The annunciator panel contains 24 annunciators, 16 of which are presently used as shown in Table XII.

When an annunciator alarm is received, the appropriate panel light flashes and an alarm horn sounds. When the acknowledge button is pushed, the horn is silenced and the light stops flashing, but remains illuminated. When the abnormal condition is corrected, the annunciator light automatically clears. A test button is provided on the annunciator panel for checking annunciator bulbs. When the button is depressed, all annunciator bulbs illuminate. All of the annunciator cover plates are white except the emergency power annunciator which, because it restricts certain normal facility operations, is red.

Two "slave" annunciators are associated with the annunciator system: one in the CPP-601 operating corridor and one in the WCF control room. The slave units are provided so an alarm received when the storage facility is unoccupied will not go unnoticed. The slave alarms are labeled "trouble GSF" (Graphite Storage Facility) and only indicate a storage facility annunciator has alarmed, not which annunciator. Thus, receipt of a storage facility alarm at either remote station requires further investigation to determine the exact nature of the alarm and the corrective action to be taken.

5. COMMUNICATION SYSTEMS

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 between the different areas. The master control unit is located in the facility control room; slave units are located in the crane maintenance and cask receiving areas.

The CPP-603 fire alarm system has been extended to include the fuel storage facility. The extension provides one fire alarm pull box for the facility between the crane maintenance area and the emergency generator room. When activated, this box transmits a coded signal within the CPP area and to the central fire station. The signal alerts personnel of a fire and informs them of the area in which the fire is located.

TABLE XII

STORAGE FACILITY ANNUNCIATORS

<u>Ann.</u>	<u>Nameplate</u>	<u>Actuates On</u>
1	Trouble-vent System 1	Loss of flow
2	Trouble-vent System 2	Loss of flow
3	Trouble-vent System 3	Loss of flow
4	Trouble-vent System 4	Loss of flow
5	Trouble-vent System 5	Loss of flow
6	Operating on standby power	Loss of normal power
7	High activity-stack gas	High level of airborne activity
8	High activity-receiving area	High level of airborne activity
9	High activity-control room and maintenance area	High level of airborne activity
10	Area direct radiation	High direct radiation
11	Maintenance area door open	Personnel door open
12	Exhaust air temperature high	High temperature
13	Storage room differential pressure	High pressure
14	Control room differential pressure	Low pressure
15	Stack flow	Low cooling air flow
16	Shielding door enclosure door open	Personnel door open

The existing CPP-603 facility does not have a plant-wide evacuation switch. However, there are three switches available at CPP-603 which will activate a local evacuation. The Irradiated Fuels Storage Facility control room has one switch and the other two switches are located elsewhere in CPP-603. In addition, the evacuation siren can be activated by the area-wide switches in CPP-601, -602, -633, or -609.

Switches that initiate both local and remote security annunciators are connected to two of the facility doors: the one entering the crane maintenance area and the one entering the shielding door enclosure. Since both areas could be high radiation zones, door alarms are provided to indicate personnel entrance into these areas. In addition, a security alarm which has a remote annunciator in the CPP guard house is attached to the shuttle bin key switch. This is the only other access opening to the storage area.

A telephone, provided and maintained by Mountain Bell, is located in the Irradiated Fuels Storage Facility control room.

V. PROPOSED FUEL HANDLING SEQUENCE

Fuel is received at ICPP in fuel shipping casks, transported by either truck or rail. Upon receipt, a cask is transferred directly to the Irradiated Fuels Storage Facility for unloading and storage of the fuel. At the storage facility, if damaged elements are suspected, a sample of the cask atmosphere is drawn through a filter cartridge into an evacuated sample bomb, and both the sample gas and the filter cartridge are analyzed to determine that the cask can be safely opened^(a), the cask is removed from the transport vehicle and positioned in the cask transfer car (Figure 27), the cask tophead closure bolts removed, and the cask prepared for unloading. When all preliminary preparations are complete, the cask transfer car is activated and the cask moved into the fuel handling cave.

When the cask is safely in the fuel handling cave, the tophead is removed and the spent fuel container or fuel basket (depending upon the cask being unloaded), removed and placed in the appropriate handling cave floor well (Figure 28). (If the cask contains Rover fuel, the poisoned cask insert is placed on the floor of the cave.) The empty fuel basket or container from the previous fuel shipment is placed in the shipping cask, the cask tophead replaced, and the cask returned to the shipper's facility. Fuel handling operations within the cave, other than unloading the cask, do not take place until the cask is removed from the handling cave.

Six Fort St. Vrain fuel elements are received in each Fort St. Vrain fuel shipment. These elements are transferred directly from the spent-fuel shipping container to fuel storage canisters (Figure 29). Each storage canister contains four fuel elements. The storage canisters are then transferred directly to the fuel storage racks. The empty spent-fuel shipping container is cleaned with the cave vacuum cleaner and stored in a floor well until the next shipment of fuel arrives and it can be returned to the reactor facility.

A Peach Bottom fuel shipment contains either 18 or 19 fuel elements arranged in a shipping basket. Each element is sealed in a separate aluminum storage can. The Peach Bottom shipping cask is handled identically to the Fort St. Vrain cask; the fuel, however, is not. Before storage in the fuel storage facility is possible, each Peach Bottom fuel element must be taken individually from the shipping basket (Figure 30), the aluminum storage can removed (cut), a portion of the upper and lower reflector cut from the element and the fuel section placed in a storage canister. The original plan was to cut the reflector sections off as shown in Figure 31 and store only the fuel section of the element in a canister as shown in Figure 32. However, information from the fuel fabricator indicated that the fuel compacts could slide out of the bottom of the sleeve if the lower reflector is cut just below the compacts. In addition, since the final site for the reprocessing demonstration plant has not

(a) If the sample indicates a contaminated cask atmosphere, a judgment will be made at that time concerning the disposition of the cask and fuel. The cask will normally be accepted and handled in the normal manner except for storage of any damaged elements in "broken element canisters". The IFSF has the facilities, including HEPA filters, to handle the contaminated casks.

Fig 27 Transferring a fuel shipping cask

Fig. 28 Unloading a fuel shipping cask

Fig 29 Placing Fort St Vrain fuel in a storage canister

Fig 30 Positioning a Peach Bottom fuel element for cutting.

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Fig 31 Cutting a Peach Bottom fuel element

Fig 32 Placing cut Peach Bottom fuel in a storage canister

been determined, it was decided to remove only enough of the top reflector to store the element in the 11-ft-long storage canister. Therefore, the cut length will be approximately 10 ft 6 in. This will make it easier to retrieve the elements for shipment to another reprocessing site if necessary. If the reprocessing facility is located at ICPP, the elements can be retrieved and cut again as necessary to process them. The criticality calculations (Appendix B) for the Peach Bottom fuel consider this additional graphite. Each canister will contain 12 Peach Bottom elements. As a storage canister is filled with fuel sections, the canister is transferred from the handling cave to the storage rack (Figure 33). When all the fuel elements in a shipping basket have been processed, the empty basket is temporarily stored in a floor well until the next shipment of fuel arrives. At that time, the empty basket is placed in the shipping cask and returned to the reactor facility. The full basket is retained at the storage facility.

The Rover fuel elements are received in LASL J-9 casks containing a poisoned insert (Figure 6) with positions for 25 cardboard tubes. Each tube contains a maximum of seven equivalent fuel elements. When received at the storage facility, the cask is transferred into the handling cave, the entire insert is removed from the shipping cask and replaced with an empty insert from a previous shipment. The cask is then removed from the handling cave, decontaminated, and returned to Nevada.

The fuel is transferred from the cask insert to the storage canister using the following sequence of operations. The two sections of a canister insert will be placed on a pedestal which will hold them side by side at a 60° angle from horizontal to facilitate loading. The lower section of a canister insert will be loaded first with a maximum of 15 cardboard tubes and will then be placed in a storage canister. The upper section will then be loaded and placed in the storage canister on top of the lower section. As subsequent shipments arrive and each canister is fully loaded, the lids will be placed on the storage canisters and the canisters will be transferred to the storage area. Since the cask will contain 25 cardboard tubes and each storage canister holds 30 tubes, it will be necessary to temporarily store partially filled canister inserts in a canister in a cave storage well or on the pedestal. The canister lids will be installed during this temporary storage in the cave storage wells if fuel other than Rover fuel is being introduced into the handling cave. The cardboard tubes will not be opened at the IFSF. A cardboard tube which is not inside the shipping container or inside a canister insert will be considered to be in the handling phase.

The graphite particles and graphite dust collected during transferring, cutting, and vacuuming operations are also placed in storage canisters; a separate canister is maintained for each fuel type. A record is kept of the weight of each "broken element" canister so that an administrative limit of two equivalent Fort St. Vrain or eight equivalent Peach Bottom elements per canister is maintained.

Full fuel storage canisters are positioned in the storage racks by fuel type. That is, Peach Bottom in one area, Fort St. Vrain in another, Rover in another. In addition, the exact location of each fuel element and each storage canister is recorded by element number, canister number, and storage rack row and position number. Through these methods, control and accountability is simplified.

Fig. 33 Placing storage canisters into the storage rack.

Conceptually, if a proposed HTGR processing facility is built, Fort St. Vrain and Peach Bottom fuel may be transferred from storage to processing with a special fuel transfer cask^(a) (Figure 14) using the wall port. To transfer fuel from storage to processing, the transfer cask could be placed horizontally on a movable dolly located in the cask receiving area. The dolly and cask are then positioned so that the end of the cask is butted against the wall port located in the fuel handling cave shielding wall. Once the cask is positioned, the dolly wheels are locked, and the cask is attached to the wall with a positive, quick-release mechanism. Fuel may then be transferred from the storage facility to the cask. To do this, the two shielding doors (one on the cask, the other on the storage facility wall) will be opened, a canister of fuel inserted into the cask cavity, and the shielding doors closed. With the shielding doors closed, the cask may be released from the shielding wall, and the dolly positioned so that the cask can be removed with the CPP straddle carrier and transported to the process headend. The fuel loading procedure will be reversed at the processing cell to unload the cask.

As designed, the fuel handling system using the wall port does not permit simultaneous handling of incoming fuel shipments and outgoing fuel transfers to processing. The system does, however, permit each operation to be performed without the other being completed. That is, either operation may be stopped at any stage of completion and the other operation performed. Other than the storage facility crane and manipulator, no equipment used in fuel receiving is used in fuel transferring. Thus, a fuel transfer cask could be positioned in the cask transfer mechanism in the fuel handling cave and could remain there regardless of the transfers to processing taking place.

Alternatively to the above described transfer procedure for HTGR fuel, it may be desirable to use a cask specifically designed and built for transfer of HTGR fuel to the process headend which can be suspended in the transfer car in the same manner as the fuel shipping casks. If this method is used, the cask will be placed in the transfer car, and the car moved into the cave. The storage canister will be placed in the cask, and the lid placed on the cask. The transfer car will be moved out to the cask receiving area and the cask will be picked up and transferred to a cradle which will permit transfer to the headend using the straddle carrier.

In the case of Rover fuel, cardboard tubes of this fuel must be transferred from the storage canister to the transfer canister which will be placed in the Rover transfer cask. This cask will be handled in the transfer car in the same manner as the fuel shipping casks.

If the transfer car is used for fuel transfer to a process headend, either receipt of shipments or transfers to process must be completed before the other procedure can be started. That is, the receipt operation and the transfer to process operation cannot proceed simultaneously.

(a) A conceptual design of this cask has been completed. The cask will be designed and built when it is required for transferring fuel.

VI. DISCUSSION AND EVALUATION OF ABNORMAL OCCURRENCES

The preceding sections of this report describe the general design of the operations and equipment in the Irradiated Fuels Storage Facility including plant features designed to protect personnel and prevent accidents. This section discusses the abnormal occurrences (potential accidents) that might involve the fuel storage facility. Although the occurrence of the postulated accidents is extremely remote, they are included to be indicative of the upper limit of the potential hazards associated with this facility. A summary of the postulated abnormal occurrences is presented in Table XIII.

1. DAMAGED FUEL ELEMENTS

Fuel elements shipped to the storage facility could be damaged either before or during shipping, or damage could occur at the storage facility during handling or cutting operations. Damage could vary from small chips or cracks to completely shattered elements.

Regardless of the amount of damage, however, all damaged elements (if accepted for storage) are handled in the same manner and, as far as possible, with standard handling tools. If normal tools and procedures are inadequate, e.g., a badly shattered element, the manipulator and cave vacuum cleaner can be used to gather the element pieces. If necessary, as specific situations arise, special procedures could be prepared and tools obtained. As a last resort, the shipping can or container could be inverted and the contents dumped into a storage canister. If dumping is used, the cave vacuum cleaner remote head would be positioned so that dusting is minimized. After the fuel has been transferred to storage canisters, the shipping cans and containers that contained the broken elements would be thoroughly vacuumed to insure complete removal of all dust and particles.

Broken elements, graphite dust, chips, etc., will be placed in special storage canisters, with a separate canister provided for each fuel type, i.e., Peach Bottom or Fort St. Vrain. The material that will be placed in each special canister is administratively limited to an equivalent, by weight, of two Fort St. Vrain or eight Peach Bottom elements. The special canisters are identical to standard canisters except that the lids have been provided with a spring steel gasket that forms a dust tight lid seal. The canisters containing broken elements will be weighed using a dial face dynamometer suspended from the crane or a visual determination of the number of broken fuel elements will be made. The location and amount in each canister will be documented in the facility log book.

In addition to being broken, fuel elements received from the Peach Bottom reactor could contain water in the aluminum storage can. The spent Peach Bottom fuel elements are stored underwater at the reactor facility for at least 120 days before being shipped to the storage facility. During this time, water could leak into a damaged storage can. The chance of such an occurrence remaining undetected, however, is very remote because:

- 1) The irradiated fuel elements are sealed in the aluminum storage cans in a dry, helium atmosphere at a pressure slightly greater than atmospheric.

TABLE XIII

POSTULATED ABNORMAL OCCURRENCES FOR THE IRRADIATED FUELS STORAGE FACILITY

Normal Operation	Postulated Abnormal Occurrence	Cause	Normal Prevention		Secondary Safeguards	Detection	Correction and/or Control	Possible Consequences of Abnormal Occurrence	
			Primary Safeguards					on This System	on Related Systems
Unloading shipping casks	Activity release	Water in a storage can	Fuel canning method at reactor facility, leak tests of shipping cans, visual observations		Cask opened in cave which has filtration on discharge air	(An activity release to the environment resulting from water in a storage can is not possible)			
		Fire	Storage facility cooling system, standby & backup emergency power		Fuel particle coatings, shipping containers	(A fuel fire during cask unloading operations is not credible)			
	Criticality	Water spacing	Storage canisters, shipping casks, and floor wells are all critically safe even if fully submerged in water (Ft St Vrain and Peach Bottom only) No water is allowed in the handling cave when fuel is present		Administrative control Fuel is permitted in the handling cave only under specified conditions No source of water in handling cave	(A criticality resulting from water or element spacing is not possible with Ft St Vrain or Peach Bottom fuel) (max $k_{eff} = 0.661$ for fuel from one Ft St Vrain block mixed with water and distributed around three blocks in a waterfilled storage canister)			
Cutting fuel	Criticality	Particle collection	Administrative control elements cut only through reflector sections Sufficient particles cannot be accumulated in a storage canister for a critical mass		Administrative control particles from each fuel type stored in separate containers, weight limit on quantities of particles stored in each canister, operator training	(A criticality resulting from a collection of fuel particles is not credible)			
Transferring fuel	Criticality	Water spacing	Storage canisters, shipping casks and floor wells are critically safe even if fully submerged in water No water is allowed in the handling cave when fuel is present		Administrative control Fuel is permitted in the handling cave only under specified conditions No source of water in handling cave, only one storage canister handled at a time	A criticality with Fort St Vrain or Peach Bottom fuel resulting from water or element spacing is impossible (max $k_{eff} = 0.661$) A criticality hazard exists with Rover fuel if more than 6.7 liters of water were to enter a canister insert of heavily loaded fuel			
		Fire	Storage facility cooling system, standby & backup fans, emergency power		Fuel particle coatings, storage canisters, filters	(A fire during fuel handling operations that could result in an activity release is not credible)			
Storing fuel	Activity release	Fire	Storage facility cooling system, standby & backup fans, emergency power		Fuel particle coatings, storage canisters, storage racks, high temperature alarms, cooling system failure alarms, filters	(A storage area fire is not credible)			
		Flood	No water permitted in the storage area, facility drain system		Fuel stored in watertight canisters, fuel particle coatings	(Water reaching the fuel as the result of a flood is not credible)			
	Radiation exposure	Earthquake	Storage facility designed to withstand SSE		None	(A radiation exposure as the result of an earthquake is not possible)		Possible destruction of cask receiving area	Possible destruction of other CPF facilities
	Criticality	Earthquake	Storage racks are designed to withstand an SSE Stored fuel is critically safe even if disturbed		Storage canisters are designed to withstand an SSE Stored fuel is critically safe even if disturbed	(A criticality as the result of an earthquake is not possible)			
		Flood	No water permitted in the storage area		Critically safe storage racks and storage canisters	(A criticality as the result of a flood is not credible, the entrances to the storage area are at least 1.6 ft above the 10,000 year flood level A criticality is theoretically possible in the Rover Zone if the facility flooded to more than 7 in A criticality is not credible as a flood is not credible)			
		Operator error	Storage racks and canisters are designed for safe storage		Administrative controls, operator training	(A criticality as the result of an operator error is not credible Multiple errors would be required)			
	Explosion	(Not possible)			Explosive materials are not present in the storage facility	NA	NA	NA	NA
		Propane gas	Propane tank 25 ft from facility, line doubly contained, flame check		Emergency generator in separate reinforced concrete room, solenoid feed valve, hand extinguisher	Visual	Routine maintenance, extinguish fire, repair damage	Possible generator damage	None
All operations	Loss of cooling	Earthquake	Facility cooling system, backup fans, emergency power		Spare fans in storage area	Visual, alarms	Repair damage, install temporary cooling system	Fan damage, possible temperature increase	None

TABLE XIII (contd.)

Normal Operation	Postulated Abnormal Occurrence	Normal Prevention		Secondary Safeguards	Detection	Correction and/or Control	Possible Consequences of Abnormal Occurrence on	
		Cause	Primary Safeguards				This System	Related Systems
		Tornado	Facility cooling system, backup fans, emergency power	Spare fans in storage area	Visual, alarms	Repair damage, install temporary cooling system	Fan damage possible temperature increase	None
	Fire	Short in electrical system	All equipment designed to electrical code, all equipment operated within rated conditions	Adequate, well located portable fire extinguishers, operator training fire alarm system	Visual	Routine maintenance, extinguish fire with fire extinguisher	Possible equipment damage or destruction	None
Checking shipping cask activity	High cask activity	Defective fuel elements	Sealed shipping cask	Cask opened in handling cave which has filtered discharge air. Cask sampled first only if damage is indicated	Analysis of cask atmosphere sample	Possibly return loaded cask to shipper	None	None
	Activity release	Inadvertent opening of sample valve	Administrative procedures - valve is to be opened only when sample bomb and off-gas connections are complete		Constant Air Monitor	Close valve	Possible high activity in cask receiving area	None
		Leaking fittings	Preventive maintenance, periodic inspection of equipment, replacement of equipment when necessary	Administrative controls, sample to be taken only by authorized person, and in approved manner	Constant Air Monitor	Tighten or replace loose fittings	Possible high activity in cask receiving area	None
		Defective sample bomb	Preventive maintenance, periodic inspection of equipment	Administrative controls, only authorized personnel to prepare bomb and take sample	Constant Air Monitor	Terminate sampling until bomb replaced	Possible high activity in cask receiving area	None
Cutting fuel	Activity release	Improper cutting	Administrative control, proper control of cutting operation, cut only through reflector sections	Direct readout of saw position, saw position controllable to $\pm 1/4$ inch, operator training	Constant Air Monitor	Stop cutting, reposition saw for new cut Stop cutting operation	Possible contamination of handling cave	None
		Fire	Administrative control, proper control of cutting operation, cut only through reflector sections	Saw mounted fire extinguisher outlet nozzle	Visual	Extinguish fire, modify cutting speed and/or location	Possible contamination of handling cave	None
	Contamination spread	Improper cutting	Administrative control, proper control of cutting operation, cut only through reflector sections	Administrative control no cutting allowed unless vacuum on, saw position readout, operator training	Constant Air Monitor	Reposition saw for new cut. Collect particles with cave vacuum	Possible contamination of handling cave	None
Storing fuel	Radiation exposure	Operator error. Operator enters high radiation area	Administrative control, controlled access to handling cave and storage area, operator training, locked access doors with alarms	Shielded walls, HP instruments and operating procedures	Visual, access door alarm	Evacuate handling cave and storage area	None	None

- 2) Each sealed can is leak-tested before being placed in the Peach Bottom storage canal.
- 3) Each can is checked for leaks as it is placed in storage, and the storage basin is rechecked at least daily to detect bubbles or any other sign of leakage.
- 4) If a leak is detected, the can is immediately removed from the canal, and after a suitable drying period (three weeks for the one storage can that has leaked), the entire storage can is sealed in a salvage can, again under a helium atmosphere, before being returned to the storage canal.
- 5) Of the more than 800 Core I fuel elements stored at the Peach Bottom reactor for greater than one year, only one can has leaked. That leak was the result of the can being damaged as it was placed in a defective storage grid. The leak was detected almost immediately, and the storage can sealed in a salvage can without further incident.

Despite these safeguards, should a fuel storage can fill with water, remain undetected, and be shipped to the fuel storage facility, a fuel-water reaction may have taken place, depending upon whether or not the fuel particle coatings were broken. As the shipping cask is transported from the reactor to the storage facility, the temperature of the fuel elements increases from less than 100°F to more than 300°F. As a result, any water present in a storage can would vaporize, increasing pressure inside of the can and force vapor and fission products out of the can into the shipping cask cavity. Therefore, if damage to the fuel is suspected, the cask atmosphere will be sampled. If necessary, the loaded cask could be returned to the reactor facility. However, incoming casks will be routinely opened in the handling cave without sampling. Any contaminants present will be safely handled by the ventilation and filtration system.

If a fuel-water reaction has not occurred by the time the cask is received at the storage facility, such a reaction is not going to occur and there is no hazard in either receiving or opening a storage can containing water. If a storage can is opened and found to contain moisture, the can will be temporarily stored intact (except for the lid) in a storage canister in a handling cave floor well until a decision is reached as to the disposition of the can and element. Unless the element is badly damaged by the water, which is highly unlikely, handling will be the same as all other elements. If the facility roof leaks, it is remotely possible for water to reach the fuel and cause a fuel-water reaction which would release fission products and generate flammable gases (H_2 , propane and/or acetylene). The amount of these gases would be small and would be swept away by the air flow over the top of the storage rack. The roof of the facility is made up of 3 ft of concrete, covered by a 3 ply built up roofing of impregnated roofing paper and roofing asphalt. This built up roofing is coved up around all equipment pads and up the parapet which surrounds the roof of the facility. Any possible water leak through this roof would be small (drips rather than streams) and would be evaporated quickly by the combination of the air flow and heat generated by the stored fuel. The canisters, while not designed to be water or air tight, have close fitting lids which would exclude nearly all of any water which might fall on the lid.

2. CRITICALITY

Although unlikely, fuel elements could be damaged during shipping and handling; and cracked, broken, or pulverized fuel elements could be received at the storage facility. Damage might also occur in the fuel handling cave during either handling or cutting operations. In any case, damaged elements would be stored in a specific storage canister used only for damaged elements. The canister will be provided with a spring steel lid gasket, and the amount of material placed in each canister will be limited to an equivalent, by weight, of two Fort St. Vrain or eight Peach Bottom elements.

Calculations^[2,3,10] made for the Fort St. Vrain, Peach Bottom, and Rover shipping casks show that a criticality incident or hazard involving these casks, assuming they are loaded with the "worst case" fuel, is impossible. The results of the calculations indicate that there can be no criticality, even if an entire shipment of fuel - six Fort St. Vrain, 19 Peach Bottom, or 175 Rover elements - were completely pulverized. Further, the six pulverized Fort St. Vrain and the 19 pulverized Peach Bottom fuels could be homogenized with water and would still remain safely subcritical.

Similar criticality calculations (Appendix B) have been completed for the fuel storage canisters with identical results - no criticality hazard exists. The various conditions for which the criticality calculations were made include:

1. Dry uncanned, closely packed elements (50 Fort St. Vrain, 100 Peach Bottom, or 343 Rover in 49 cardboard tubes) partially concrete reflected.
2. Same as 1 except 448 Rover elements in 64 cardboard tubes.
3. Two hundred sixty loaded fuel storage canisters, closely packed, partially concrete reflected.
4. A full fuel storage facility under normal storage conditions (see Section III.5.5).
5. A fuel storage area with all of the Rover fuel (200 positions), all of the Peach Bottom fuel (75 positions), and the remainder of the facility loaded with Fort St. Vrain fuel.
6. Same as 4 except Rover is loaded at 18 tubes per canister insert and all tubes are loaded with 1120 g U-235 and 6 kg carbon.
7. One full fuel storage canister surrounded by an infinite water reflector^(a,b).

(a) A full canister contains either 4 Fort St. Vrain or 12 Peach Bottom fuel elements.

(b) All water calculations are included simply as an indication of the criticality safety level of these fuels. A CPP-603 flood is not credible^[11]

8. One fuel storage canister, filled with water, surrounded by an infinite water reflector (Fort St. Vrain and Peach Bottom fuels only).
9. One full fuel storage canister, filled with water, surrounded by an infinite water reflector, with the fuel particles removed from some of the elements and accumulated in the bottom of the canister surrounding the other elements (Fort St. Vrain and Peach Bottom fuels only).
10. Same conditions as 4 except that the storage area is flooded with water to a depth of 44 in. (Peach Bottom and Fort St. Vrain fuels only).

An evaluation was also made of the criticality hazard due to partial water moderation while Rover fuel is present. This evaluation (no specific calculations were made) concludes that partial water moderation due to humidity in the air is not a problem. That is, the partial water volume fraction due to 100 percent relative humidity at 100°F is several orders of magnitude below the point at which partial moderation begins to have an effect on reactivity. However, if water were to enter the facility and leak into a canister and into the canister insert (highly unlikely but possible), as little as 6.7 liters of water could possibly cause a criticality in one canister. In addition, if the water level in the facility were to rise around the canister to a level of more than approximately 7 in. (the bottom of the Rover tubes are 5 in. from the bottom of the canister and the bottom of the canister is approximately 2 1/2-in. from the floor), a criticality could possibly occur. However, the design of the canister lids will prevent leakage of more than a few drops of water into the canister and the design of the facility will prevent flooding or leakage of amounts of water necessary to build up to a level of 7 in. (approximately 7000 gal). The storage area drain system will remove any accumulation of water and the SOP's for operation of the facility require inspection for water and checking of the drain system on a regular basis. The drain valves are kept locked open to prevent any possibility of water accumulating in the facility.

The above situations represent all possible (and several impossible) fuel storage conditions. As shown in Table XIV nearly all conditions are critically safe even though a number of conservative assumptions were used in the calculations: new fuel elements, the most reactive fuel elements, and no burnable poisons or other nonfuel neutron absorbing materials present. Based on control of water loading and spacing, an accidental criticality hazard involving graphite fuel in the Irradiated Fuels Storage Facility is considered incredible. These calculations show that even with deliberate action, a criticality would be difficult to achieve.

Figure 34 shows k_{eff} for various loadings of Rover fuel stored with Fort St. Vrain and Peach Bottom fuels occupying the remainder of the storage positions. The loading limit of 12.6 kg U-235 per canister insert (25.2 kg per storage canister) was based on the data presented in these curves. Study of the curves shows that the k_{eff} is not a simple relationship with U-235 mass. The amount of carbon present, including that contributed by the cardboard tubes, has an effect on the k_{eff} . The storage configuration chosen is a safe arrangement which allows a reasonable storage density for economical use of storage space.

Fig. 34 k_{eff} versus Rover loading mass when stored with Fort St. Vrain and Peach Bottom.

TABLE XIV

 k_{eff} FOR SEVERAL DIFFERENT FUEL STORAGE CONDITIONS

	k_{eff}		
	Fort St. Vrain	Peach Bottom	Rover
1. Dry, uncanned, closely packed fuel elements (50 Fort St. Vrain ^(a) , 100 Peach Bottom, or 343 Rover ^(b) , partially concrete reflected.	0.752	0.859	0.943
2. Same as 1, except 448 Rover elements ^(b) .			1.0
3. Two hundred sixty dry, close-packed fuel storage canisters partially concrete reflected ^(c) .	0.967 ^(d)	0.952 ^(d)	
4. Full storage facility, normal storage conditions (see Sec. III.5.5)(scoping calculation, loading limits have changed).	0.575 ^(e)	0.821 ^(d)	0.893 ^(f)
5. Facility fully loaded with maximum loaded Peach Bottom (19 elements per canister) in 75 positions. Fort St. Vrain (4 elements per canister) and Rover [15 cardboard tubes per canister insert, 12.6 kg U-235 per canister insert (840 g U-235 average per cardboard tube), 1120 g U-235 maximum per cardboard tube, 6 kg carbon per cardboard tube 200 positions loaded] ^(g) .	All fuels together 0.912 (maximum loading for storage, see Fig. 34)		
6. Same as 4 except Rover is loaded at 18 cardboard tubes per canister insert; all cardboard tubes contain 1120 g U-235 and 6 kg carbon for a total of 20.16 kg U-235 per canister insert ^(h) .	All fuels together 1.0		
7. One full canister ⁽ⁱ⁾ , dry, surrounded by an infinite water reflector.	0.385	0.379	
8. One full canister, water-filled, surrounded by an infinite water reflector.	0.633	0.796 ^(d)	

TABLE XIV (contd.)

	k_{eff}		
	Fort St. Vrain	Peach Bottom	Rover
9. One full canister, water-filled, surrounded by an infinite water reflector, all the fuel particles accumulated in the bottom of the canister.	0.661	0.528 ^(d)	
10. Same as 4 except 44 in. of water in the storage area.	0.478	0.787	
11. Full shipping cask flooded with water; all fuel particles leave the elements and form a homogeneous mixture with the water; mixture is at a height of 214 cm ^(j) .	0.890 ^[2]	0.720 ^[3]	
<hr/>			
(a) Arranged as shown in Fig. 35.			
(b) Arranged as shown in Fig. 36, 7 Rover elements per cardboard tube, 1120 g U-235 per cardboard tube.			
(c) Arranged as shown in Fig. 37, 4 Ft. St. Vrain or 12 Peach Bottom elements per canister.			
(d) Aluminum canister, 8 ft high (conservative calculation).			
(e) Steel canister, 11 ft long (actual storage case).			
(f) One hundred ten canisters filled with Rover fuel.			
(g) This loading assumes an average loading of 840 g U-235 per cardboard tube for a total of approximately 5000 kg of U-235. The actual total is approximately 2600 kg U-235 to be stored in 160 positions for an average of approximately 540 g U-235 per cardboard tube.			
(h) This loading assumes all tubes at 1120 g U-235 for a total of approximately 8000 kg of U-236. Individual tubes may contain 1120 g of U-235 but the average over the storage area will be approximately 540 g U-235 per cardboard tube.			
(i) Four Fort St. Vrain or twelve Peach Bottom elements.			
(j) The most reactive height.

Fig. 35 Calculational model for dry, uncanned, closely packed, partially concrete reflected fuels.

Fig. 36 Model for Rover criticality calculations.

Fig 37 Calculational model for close packed square pitch, partially concrete reflected canisters of fuel.

The highest k_{eff} calculated for Peach Bottom fuel was 0.952. This is equivalent to 3.8 cores of Peach Bottom fuel in a close-packed array of 20 x 13 x 1 canister. Only one core of Peach Bottom fuel will be stored in the Irradiated Fuels Storage Facility.

The highest k_{eff} calculated for Fort St. Vrain fuel was 0.967; this is equivalent to nearly one full core of Fort St. Vrain fuel in a close-packed array of 20 x 13 x 1 canisters. An array of this size cannot exist in the cave or above the rack in the storage area because of space limitations. This size array could exist in the storage area but could not be close packed. Thus, close-packed arrays of 260 canisters of Peach Bottom or Fort St. Vrain fuels are impossible. The cases were chosen to indicate an upper limit of safety, not whether the space or configurations were possible.

The highest k_{eff} shown for Rover fuel is 0.943 for 343 elements in 49 cardboard tubes - nearly two full shipments of elements - arranged as shown in Figure 36. The estimated failure level (EFL) for Rover fuel in a close-packed array is approximately 64 cardboard tubes each loaded with seven of the most reactive elements (160 g U-235 per element with maximum possible excess graphite at $\rho = 1.9 \text{ g/cc}$ and arranged as shown in Figure 36. Thus, more than two shipments of fuel (more than double batching) is required to effect a criticality. In addition, procedures permit handling of only one cardboard tube at a time.

Even though criticality is not a problem because of the facility design and enforced administrative procedures, an additional precaution taken in the design and operation of the storage facility is the exclusion of all sources of water from the fuel storage area and the fuel handling cave. This restriction serves two purposes: it further reduces the possibility of a criticality incident, and eliminates any possibility of a fuel water reaction.

In addition to physical means, administrative procedures are also used to prevent criticality incidents. These procedures:

1. Prohibit handling more than one fuel element or cardboard tube at a time, except when the elements are in an approved container, such as a shipping basket, spent fuel container, or storage canister.
2. Control the number of shipments of fuel in the handling cave at any one time^(a).
3. Prohibit storing fuel in the fuel storage area in any container other than a standard fuel storage canister.
4. Prohibit placing of fuel in any location in the handling cave except in approved storage canisters, canister inserts, or shipping containers and then only in a cave floor well, the shuttle bin, or on the pedestal.

(a) Fifteen fuel storage wells are provided in the fuel handling cave should circumstances (equipment breakdown, simultaneous arrival of two or more shipments) require temporary storage of more than one fuel shipment. These circumstances will be controlled by approved SOP's. These wells also permit the temporary storage of an entire shipment of fuel from a future HTGR 1100 reactor.

5. Limit Rover loading to a maximum of 1120 g U-235 and 6 kg fuel mixture per cardboard tube and 15 tubes containing a maximum of 12.6 kg of U-235 per canister insert, and two inserts per canister.

It is not necessary to place administrative controls on the number of fuel elements permitted in the cave for the following reasons:

1. For Peach Bottom and Fort St. Vrain fuel, it is not possible to place enough canisters of fuel in the cave to obtain a criticality.
2. The spacing of the cave floor storage wells is greater than the spacing in the storage area so a criticality from canisters of fuel in 15 storage wells is impossible.
3. Except under accident conditions, i.e., inadvertent release of a canister while being carried by the crane, canisters of fuel will not be placed in any position other than the cave floor wells or the shuttle bin. The design of the crane grip would make it difficult to stand a canister in the corner or lay a canister on the floor.
4. The administrative controls listed above will place controls on how fuel is handled, i.e., where the fuel is placed and how many are handled at one time. (See Bases, Appendix F.)
5. If the administrative controls were violated, it would require more than two complete shipments (double batching) of any fuel to cause a criticality. For example, Fort St. Vrain fuel is safe in a 5 x 5 x 2 array which is more than eight shipments of fuel; for Rover fuel, 64 tubes (more than two and one half shipments) of the most reactive Rover fuel with maximum excess graphite would be required in a close-packed array to cause a criticality.

The stored fuel is maintained in a critically safe array by the carbon steel fuel storage racks. These racks position the storage canisters on a critically safe two-foot center-to-center spacing, assuming the facility is full of fuel. The vacuum canister has also been examined from a criticality viewpoint. Because of the small size of this canister (10 gal), a criticality with this vessel either wet or dry is impossible. That is, not enough of any graphite fuel (from Fort St. Vrain or Peach Bottom fuel elements) can be placed in the canister to cause a critical condition. Since Rover fuel is contained in individual cardboard tubes, it is highly unlikely that enough fuel from broken tubes could accumulate to cause a criticality.

Calculations have also shown that it is safe to store fuel in any or all of the cave floor wells. The spacing is greater than the storage area spacing. Assuming all 15 wells plus the shuttle bin contain fully loaded canisters of Rover fuel (30 cardboard tubes per canister), a k_{eff} of 0.309 was calculated. Since Rover is the most reactive fuel, any other arrangement would result in a lower k_{eff} .

3. FISSION PRODUCT RELEASE

Significant fission product and heavy element inventories (in curies) for irradiated Peach Bottom and Fort St. Vrain fuel elements are shown in Tables XV and XVI, respectively. The fission product inventories^[12] are based on 2.5 yr of reactor operation at 114 MW for Peach Bottom, and 6 yr at 837 MW for Fort St. Vrain. In both cases, the fuel has a 120-day cooling time.

As shown in the tables, a significant fission product inventory is present in the irradiated fuel. However, the fission products are contained within the fertile and fissile particles, both of which are coated with pyrolytic carbon (Figure 38) that serves as the prime barrier for retaining the fission products. In addition to the pyrolytic carbon coating, the Fort St. Vrain particles are also coated with a layer of silicon carbide and then a second layer of pyrolytic carbon to further improve the fission product retention characteristics of the fuel.

Tests^[13,14] on the coated particles have shown 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, and that fission products can be driven from the fuel particles, but only in insignificant quantities at temperatures below 1,000°F. Additional experiments^[15] with graphite fuels have shown that the release of stored fission products from the coated particles is not rapid until a temperature near the melting point of uranium-thorium carbide (4450°F) is reached. Since, under normal storage conditions, the centerline temperature of the hottest stored fuel elements will remain below 365°F, no release of fission products is expected.

Even though the possibility of a fission product release is remote, calculations have been performed to determine the maximum dose that could be received at the INEL site boundary from the sum of all the fission products contained in one canister^(a) of fuel. The calculations were based on the following:

1. One percent^(b) of the fuel particles have ruptured coatings; fission products can only be released from particles with failed coatings.
2. The guidelines of 10 CFR 100^[17] apply, i.e., for a person in an unrestricted area, the whole body dose must not exceed 25 rem, and the thyroid dose must not exceed 300 rem.
3. A TID-14844^[18] release applies, i.e., 1 percent of the solids, 50 percent of the halogens, and 100 percent of the noble gases, except no credit is taken for plateout, absorption, etc.

(a) The maximum amount of fuel that can be affected by an accident, since each canister of fuel is an independent storage unit, i.e., there is no interaction between canisters.

(b) Shown by extensive tests^[16] to be the maximum upper limit of particle coatings expected to fail at full burnup.

TABLE XV

PEACH BOTTOM FUEL ELEMENT FISSION PRODUCT INVENTORY
(900 Equivalent-Day Core, 120-Day Cooled)

<u>Isotope</u>	<u>Activity (curies)</u>
Kr-85	5×10^1
Sr-89	1.17×10^3
Sr-90	3.93×10^2
Y-90	3.93×10^2
Y-91	1.73×10^3
Zr-95	2.1×10^3
Nb-95	3.98×10^3
Ru-103	4.8×10^2
Rh-103m	4.8×10^2
Ru-106	4×10^2
Rh-106	4×10^2
Te-127m	2.2×10^1
Te-127	2.2×10^1
Te-129m	3.1×10^1
Te-129	3.1×10^1
Cs-137	6×10^2
Ba-137	6×10^2
Ba-140	1.8
La-140	2
Ce-141	6.35×10^2
Pr-143	1.9×10^1
Ce-144	5.06×10^3
Pr-144	5.06×10^3
Pm-147	1.5×10^3
Sm-151	1.3×10^1
Pa-233	2.2×10^4
U-233	4.2×10^{-1}
U-234	4.65×10^{-2}
Pu-238	9.5
Pu-239	2.69×10^{-2}
Pu-240	2.3×10^{-2}
Pu-241	2×10^1

TABLE XVI

FORT ST. VRAIN FUEL ELEMENT FISSION PRODUCT INVENTORY
(Six-year Equilibrium Core, 120-Day Cooled)

Isotope	Activity(curies)	Isotope	Activity(curies)
Kr-85	5.73×10^2	Nd-147	4
Sr-89	3.93×10^3	Pm-147	6.1×10^3
Sr-90	3.17×10^3	Sm-151	7.4×10^1
Y-90	3.17×10^3	Eu-154	4.5
Y-91	4.51×10^3	Eu-155	4.3×10^1
Zr-95	6.16×10^3	Ra-224	7.11×10^2
Nb-95	1.19×10^4	Ra-228	1.1×10^{-2}
Ru-103	8.29×10^2	Ac-228	1.1×10^{-2}
Rh-103m	8.29×10^2	Th-228	3.65×10^{-1}
Ru-106	8.13×10^2	Th-230	7.03×10^{-4}
Rh-106	8.13×10^2	Th-234	6.5×10^{-1}
Sn-123	2.9×10^1	Pa-231	2.03×10^{-3}
Sb-125	7.5×10^1	Pa-233	1.34×10^4
Te-125	4.6×10^1	Pa-234	6.5×10^{-1}
Te-127m	7.5×10^2	U-232	2.04
Te-127	7.5×10^2	U-233	2.25
Te-129m	2.4×10^2	U-234	3.04×10^{-1}
Te-129	2.4×10^2	Np-237	1.12×10^{-2}
Cs-134	6.4×10^1	Pu-238	1.19×10^2
Cs-137	3.21×10^3	Pu-239	9.61×10^{-2}
Ba-137m	3.21×10^3	Pu-240	8.54×10^{-2}
Ba-140	3.1×10^1	Pu-241	4.8×10^1
La-140	3.5×10^1	Am-241	8.7×10^{-2}
Ce-141	1.9×10^3	Am-242m	6.03×10^{-3}
Pr-143	5.4×10^1	Am-243	3.71×10^{-2}
Ce-144	1.48×10^4	Cm-242	2.7×10^1
Pr-144	1.48×10^4	Cm-243	9.9×10^{-3}
		Cm-244	6.18

Fig. 38 Coated fuel particles.

4. The fission products are released from the storage facility stack, the top of which is 65 ft above ground.
5. Fumigation meteorological conditions exist at the time of the release.
6. The prevailing windspeed is 2 meters/second, directed towards the nearest site boundary.
7. The release occurs over a 15-minute to 3-hour period.
8. The storage facility exhaust air filtering system is completely ineffective.

Even though most of the above assumptions are conservative, the calculations indicate that from all the nuclides present in the fuels, including heavy metals, the total whole body dose at the site boundary would be 9.1 and 28 mrem for a storage canister of Peach Bottom and Fort St. Vrain fuel, respectively. Both values are well below allowable limits. Should the postulated accident involve an entire shipment of fuel, 18 Peach Bottom or six Fort St. Vrain elements, the whole body dose at the site boundary would still remain well below acceptable limits: 14' and 42 mrem for Peach Bottom and Fort St. Vrain, respectively.

Simply for comparison purposes, on-site doses for a receptor located 100 meters downwind of the release were also calculated. Even these doses were less than allowable off-site limits.

If a dose calculation is made for only the plutonium contained in a full shipment of fuel, the doses received by an off-site receptor are as follows:

<u>Off-Site Receptor Dose (rem) From Plutonium</u>		
<u>Organ</u>	<u>Fort St. Vrain</u>	<u>Peach Bottom</u>
Body	0.028	0.007
Bone	1.13	0.28
Liver	1.39	0.06

Again, all are well below acceptable limits (Appendix D).

Similar calculations^[19,20] have been completed for the Rover fuel. These calculations indicate that for approximately similar assumptions as those made for Fort St. Vrain and Peach Bottom, the maximum dose would be an insoluble lung inhalation dose of approximately 288 mrem. This is well below the 100 rem maximum acceptable level for lung irradiation under accident conditions for an unrestricted area.

A summary of the calculated off-site and on-site doses is presented in Table XVII. and detailed dose calculations are presented in Appendix E.

TABLE XVII

RECEPTOR DOSE AS A FUNCTION OF FUEL ELEMENTS POSTULATED DESTROYED

<u>Fuel</u>	<u>Elements Destroyed</u>	Maximum Off-Site Doses (rem) ^(a)	
		<u>Body</u>	<u>Bone</u>
Fort St. Vrain	1	0.0071	0.23
	4	0.028	0.92
	6	0.043	1.38
Peach Bottom	1	7.6×10^{-4}	0.022
	12	0.00912	0.264
	18	0.137	0.396
Rover	250	(lung 0.288 rem)	

<u>Fuel</u>	<u>Elements Destroyed</u>	Maximum On-Site Doses (rem) ^(b)	
		<u>Body</u>	<u>Bone</u>
Fort St. Vrain	1	0.497	15.9
	4	1.99	63.6
	6	2.98	95.4
Peach Bottom	1	0.053	1.52
	12	0.636	18.2
	18	0.954	27.4

(a) At site boundary.

(b) 100 meters downwind of stack.

Fission products could also be released through hydrolysis of the fuel^(a) should, by some unknown method, water contact the fuel. Again, however, fission products would only be released from particles with failed coatings. During hydrolysis of the failed particles, most of the noble gases would be released to the atmosphere; soluble fission products would be retained in the water. If a hydrolysis reaction occurred, Kr-85 would be the only fission product released. Assuming a 1% coating failure upper limit, and a Kr-85 inventory of 573 curies per Fort St. Vrain element, a hydrolysis reaction of one cask of fuel could release 34 curies of Kr-85. A cloud dose calculation was made to determine the maximum expected receptor dose, based on the following "worst case" assumptions:

1. An instantaneous puff release of the Kr-85.
2. A lapse meteorological condition for the duration of the release with "looping" bringing the plume down to the receptor position 100 meters downwind.
3. A wind speed of 6 meters/second.
4. A 10-second exposure time to the cloud (duration during passage of the plume).

Based on these assumptions, the receptor dose was calculated to be 7 mrem, well below the guidelines of 10 CFR 100. A plot showing receptor dose as a function of downwind distance is shown in Figure 39. Similar calculations have been made for a cask of Peach Bottom fuel even though a hydrolysis reaction involving this fuel is practically impossible because the elements are shipped in watertight cans. These calculations indicate an even smaller dose than that calculated for Fort St. Vrain. Therefore, the occurrence of a serious accident involving the graphite fuel that releases a significant amount of fission products is considered incredible.

4. RADIATION

The irradiated graphite fuel will have an average cooling time of approximately 180 days when received at the fuel storage facility, and thus will present a significant radiation hazard if unshielded. This potential radiation hazard will be controlled through the use of shielding, instrumentation, and administrative procedures.

Shielding walls and windows, and shielded casks protect personnel during fuel transport, handling, and storage. At no time are shipping casks opened or is fuel handled outside the storage facility. Rather, all fuel handling operations are performed in the handling cave and the fuel storage area using remote methods, and sufficient shielding is provided in the facility so that radiation levels at grade in areas that are external to the storage facility and accessible to personnel never exceed 2.5 mrem/hr.

(a) Rover fuel, because of its low burnup and correspondingly low fission product inventory, was not considered in this analysis.

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Fig. 39 Receptor dose from a water-fuel reaction.

Inside the facility (except the control and instrument rooms), once fuel is present, a relatively high radiation level will exist. To control access to the facility and prevent an 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 will normally be locked, and access will only be possible with proper authorization. Before personnel access to the facility is permitted, all fuel will be removed from the fuel handling cave and the movable shielding door closed to minimize radiation levels in the crane maintenance and fuel handling cave areas.

Administrative procedures, safe work permits, and radiation instruments are also used to protect personnel from high radiation exposure. In addition, Health Physics coverage is provided along with dosimeters.

5. FIRE

The possibility of a storage facility fire is extremely remote. The facility is constructed entirely of concrete and steel, and has thick concrete shielding walls installed between functional areas. Thus, the facility itself will not support combustion, and combustible materials^(a) (other than a few cardboard tubes for the Rover fuel) will not be stored in the facility. However, should a fire be postulated (for example, electrical or control cables), the internal shielding walls will contain the fire to the area in which it occurs. Since interaction between areas is highly improbable, the fire potential of each area and the fuel itself is discussed separately.

5.1 Graphite Fuel Characteristics

Graphite is neither a combustible nor an explosive material. Oxidation begins to occur at elevated temperatures, with the rate directly proportional to the temperature. Generally, the oxidation reaction ceases when the heat source is removed. For these reasons, and others outlined in the following paragraphs, a fire involving the stored fuel is not credible.

5.1.1 Graphite Oxidation Temperature. Graphite does not measurably oxidize at surface temperatures below about 1000°F^[21] Under normal storage conditions, the centerline temperature of the hottest stored fuel will be approximately 365°F, well below graphite oxidation temperatures. Tests conducted at ICPP showed that under ideal conditions^(b) graphite fuel began spontaneous oxidation at 1100°F. Thus, an upper temperature limit of 1100°F has been established as the maximum allowable temperature of the stored fuel. The spontaneous oxidation reaction experienced during the ICPP tests, however, consisted simply of the graphite glowing (no open flames), and oxidation could

(a) Graphite is noncombustible. However, very slow oxidation does begin to occur at temperatures above 1000°F.

(b) Small fuel particles distributed in a heated, fluidized bed, and under a forced air atmosphere.

only be sustained by the continued forced circulation of combustion air. Tests^[22] by the United States Bureau of Mines of ten graphite dust samples dispersed in air indicate that none of the samples would ignite with a spark, and only five of the ten would ignite in a high temperature furnace. None had initial burning temperatures below 1546°F. In addition, regardless of the particle size, concentration, or temperature, the graphite sample could not be made to explode. Further tests at ICPP with graphite rods in closed containers designed to be analogous to Irradiated Fuels Storage Facility canisters indicates that essentially no oxidation occurs at a temperature of 1400°F. In closed containers, graphite will not burn at 1400°F^[23]. Thus, graphite is a relatively inert material and 1100°F is a reasonably conservative upper limit for the centerline temperature of the stored fuel.

5.12 Ability of Stored Fuel to Support Oxidation. The method of storing the spent fuel, i.e., closed, spaced canisters, serves to prevent spontaneous oxidation of the fuel and any interaction between canisters. The tight-fitting lid will close each canister and prevent air, other than the small amount present in each canister, from reaching the fuel while the canister itself, being steel, will rapidly transmit the decay heat to the cooling air. The storage racks space the canisters so nuclear interaction is impossible, and also stagger the canisters for effective and efficient heat transfer. In addition, the racks enclose the canisters for positive cooling, and the cooling system has a double system of automatic start backup blowers. With these design precautions, an oxidation reaction of the fuel would require the incredible conditions of complete failure of the cooling system for an extended period of time and complete failure of the storage canisters.

5.13 Self-Extinguishing Characteristics. As mentioned previously, a serious fire within the storage facility must be based on a complete loss of cooling air flow. Assuming this condition occurred, the temperature of the fuel would rise and at approximately 1000°F slow oxidation could begin. If the air within the storage facility at the time of the loss of coolant is assumed to contain 20 weight percent oxygen and to be at standard conditions, approximately 64 pound-moles of oxygen are contained within the facility. If an additional assumption is made that no air flows into the facility during the loss of coolant, approximately 128 pounds moles of graphite (about that present in 18 Peach Bottom or 6 Fort St. Vrain elements) could be oxidized^(a) before the reaction ceased from the lack of oxygen. Thus, if a complete and extended loss of coolant were postulated, the oxidation reaction would be self-extinguishing. On the other hand, if only a partial loss of coolant were postulated, the oxidation reaction probably would not occur because even a limited air flow would provide sufficient cooling to maintain fuel temperatures below 1100°F for several days, sufficient time to permit corrective action to be taken. For example, if the air flow were 120 cfm, the temperature of the freshest fuel would remain below 1100°F for more than five days.

5.14 Fuel Temperature Analysis. Several heat transfer analyses have been performed on the stored fuel using the SINDA-3G, the CSMP, and the SIMIR computer codes. The details of these calculations are presented in Appendix A. Briefly, however, the analyses

(a) Assuming that: (1) the air can gain access to the fuel, and (2) CO rather than CO₂ is formed.

show that for the design cooling air flow rate of 12,000 cfm, the maximum fuel element temperature (centerline) is 193°F for an average^(a) element and 365°F for the hottest element; the exit air temperature is less than 190°F. The studies further show that upon a total loss of coolant, a minimum of 28 hours is available in which to take corrective action before the temperature of any fuel element reaches 1100°F.

Based on the above fuel characteristics and fuel storage methods, the fire hazard associated with the fuel storage facility is negligible, and a fire in the fuel storage area is considered incredible. The only possible hazard associated with the stored fuel is the postulation of a complete loss of coolant. Even in this case, sufficient time is available in which to take corrective action. Therefore, because of the low probability of a fire and the desirability of keeping water away from the fuel, no storage facility fire precautions have been taken other than cooling air, steel storage canisters, enclosed storage racks, and portable extinguishers in specified areas of the facility where fire is possible but highly unlikely.

5.2 Fuel Storage Facility

The ICPP fire water system serves the fuel storage basin building (CPP-603), the cask receiving building, and the fuel storage facility. However, because of the potential fuel-water reaction, water pipes are not present in the handling cave or storage area, and water will not be allowed in these areas when fuel is present. The possibility of a roof leak was discussed in Section VI.1. Fire extinguishers are provided in the control room and the generator room. These rooms are the only normally accessible areas in the facility.

5.21 Control Room. The primary fire potential in the facility control room is in the instrumentation, electrical, and control wiring. Since fuel is not stored in this area, and the value of the total electrical system is approximately \$35,000, an automatic fire suppression system is not required. Fire protection is provided by several portable extinguishers suitable for use on electrical fires. (AEC Manual Appendix 6301, Part I, requires a fire suppression system if the value exceeds \$100,000).

5.22 Fuel Handling Cave. Electrical fires could occur in the fuel handling cave. And, although the possibility is remote, if conditions were correct, a graphite fire (a rather slow oxidation—no flames) could also occur in this area. The most probable place and time of a fire in the handling cave would be at the remote saw during fuel cutting operations. Any fire which would occur would be due to the heat generated by friction at the cutting point. The CO₂ fire extinguishing agent will act to cool the point of application and stop any oxidation which occurs. In addition, a small percentage of the CO₂ may react with the hot graphite to generate CO. This reaction is endothermic and would aid in the cooling of the oxidizing surface. The amount of CO generated would be small and would be quickly removed by the ventilation system and the vacuum system. Therefore, the saw is equipped with a temperature sensor and a high temperature alarm, and a control room-mounted and

(a) The total heat generation rate divided by the total number of stored elements.

operated CO₂ fire extinguisher, the outlet of which is piped to the handling cave and directed at the cutting operation. This extinguisher can also be discharged through a 10-ft long hose located in the handling cave above the vacuum canister. Fire extinguishers are also located near the door to the crane maintenance area and, if the need arises, can be used either directly or remotely in both the crane maintenance area and the fuel handling cave. Combustible materials will not be permitted in the handling cave when fuel is present. It may be desirable to cover the casks with plastic while in the cave to aid in decontamination of the casks. This will be temporary and no fuel handling will be done while the cask is in the cave. The plastic will be attached to the cask and will be removed with the cask when it is moved out of the transfer car.

5.23 Crane Maintenance. 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 would combat it directly using portable fire extinguishers mounted in the crane maintenance area.

5.24 Cask Receiving Area. When fuel is present in the cask receiving area, the fuel is always contained in a sealed fuel shipping cask, and a fuel-water reaction is not possible. Therefore, manual hose stations connected to the ICPP fire water system provide protection for the cask receiving area. In addition to hose stations, suitable portable fire extinguishers are also available for use on fires where water is not a suitable extinguishing agent.

5.25 Fuel Storage Area. The irradiated graphite fuel elements are stored in the fuel storage area of the facility in 1/4-in.-thick steel canisters with tight-fitting lids. The canisters, in turn, are placed in carbon steel racks which position the canisters on 24-in. centers and in a staggered arrangement (see Figures 12, 16 and 17).

The fire potential associated with this area of the facility is considered negligible because of: (a) the construction of the facility, (b) the method of storing the fuel, (c) the characteristics of graphite fuel, and (d) prohibiting the storage or use of combustible materials in the storage area when fuel is present, other than the cardboard tubes containing the Rover fuel. Tests have shown that individual cardboard tubes will not support combustion. Therefore, other than the cooling system described in Section III.8.6, no fire prevention or fighting equipment is located in this area. The high temperatures which could be generated by the Fort St. Vrain or Peach Bottom fuels are self generated, and the Rover cardboard tubes will not experience these high temperatures. A discussion of the facility and the fuel storage method was presented in Section III.5; a physical description of the fuel was presented in Section II.

5.26 Emergency Generator. The chance of a propane fire or explosion is very remote, and there is no way that such an event could affect the stored fuel. The system is designed with a number of safety features which essentially eliminate any hazard. These features include the following:

1. The propane tank is located about 25 ft from the emergency generator room and the storage facility, and is provided with a manual shutoff valve.

2. The propane feed line is a contained line, i.e., a feed pipe inside a larger containment pipe.
3. The propane containment line is provided with a flame check, i.e., a vent to atmosphere to prevent gas buildup in the event of a feed-line leak.
4. There is a limited supply of fuel (500 gal) available, so a propane fire would be self-extinguishing.
5. A feed-line solenoid valve opens only upon receipt of a "generator-start" signal and closes when generator operation ceases. Thus, fuel is available only during generator operation. In addition, a second manual shutoff valve is provided between the feed-tank valve and the solenoid valve just inside the emergency generator room.
6. Hand fire extinguishers are available in and near the generator room.

In addition, the emergency generator is located in a separate, reinforced concrete room and interaction with the stored reactor fuel is impossible.

6. FLOOD

The desert-like area in which the INEL is located has a less than remote chance of ever being flooded^[5]. The nearest major river, the Snake, lies 50 miles east. Smaller streams, e.g., Big Lost River, Little Lost River, and Birch Creek, disappear into the porous lava formations underlying the site.

Localized flooding conditions have occurred at the INEL during spring runoff periods, but none affected the ICPP area in the 20-year period the ICPP has been in existence. A maximum potential (10,000 year) flood has been postulated^[6,11] for the ICPP area that would reach a datum elevation of 4916.6 ft. The fuel storage facility floor elevation is 4918.2 ft. Thus, the water level produced by this flood is 1.6 ft. lower than the facility floor level. This difference in elevation and the slope of the land around the building would prevent the water from approaching closer than approximately 1/4 mile from the facility. Thus, a flood affecting the storage facility is not credible. Simply to obtain an indication of the level of safety associated with these fuels, however, various conditions involving fuel that might occur during a flood have been postulated and a k_{eff} calculated for each condition. The results of the calculations were presented in Section VI.2 and Table XIV. As the calculations show, even assuming conservative conditions of: (a) the most reactive fuel elements, (b) all fuel particles leaving the flooded elements, (c) the graphite fuel structure remaining intact, and (d) a homogeneous mixture of fuel and water, the calculated k_{eff} is always less than unity except for Rover fuel which could theoretically go critical if the storage area were to flood.

Water in the storage facility could result in a fuel-water reaction and a possible fission product release. As discussed in Section VI.3, however, any releases would be well below acceptable limits.

7. EARTHQUAKE

Tentative regulatory criteria^[24] define a Safe Shutdown Earthquake (SSE) for any area as the earthquake which could cause the maximum vibratory ground motion at that site, and further states that all features of a facility necessary to effect safe shutdown of the facility and maintain it in a safe condition must remain functional during and following an SSE.

The ERDA's General Design Criteria, AECM Appendix 6301, specifies the Uniform Building Code (UBC) as the basic code to be followed in designing ERDA structures. A seismic risk map of the United States is included as part of the UBC code. The map was recently revised and now appears as shown in Figure 40. As can be seen, this revision changed the earthquake risk classification of the INEL from Zone 2 to Zone 3. A directive^[25] accompanying the revision stated that all future INEL structures will be designed to Zone 3 seismic criteria.

A recent study^[26] of the seismology of the INEL conservatively established an ICPP bedrock acceleration range of 0.15 to 0.33 g. The storage facility features necessary to maintain the plant in a safe condition without undue risk to the health and safety of the public are designed for an SSE having 0.33 g bedrock acceleration. Based on ICPP soil conditions, i.e., 30 ft of sand and soil above bedrock, an amplification factor of 1.3 was applied to the structure, yielding a total design load of 0.43 g. Those portions of the storage facility not required for protection of the public (everything except the storage building) are designed in accordance with the UBC Seismic Risk Zone 3 criteria. Thus, although the SSE may cause damage to parts of the storage facility, i.e., the cask receiving area, all systems necessary to maintain the plant in a safe condition without undue risk to the health and safety of the public are designed to remain functional.

8. TORNADO

The tornado design requirements for the storage facility are similar to those for the earthquake, i.e., that appropriate critical features of the facility needed to limit the consequences of the tornado must remain operable and maintain their functional design performance requirements. A recommendation^[27] was made that the design basis tornado (DBT) for the ICPP area be established as an upper wind velocity limit of 175 mph, including a translational velocity component of 25 mph, and a rotational (tornadic) component of 150 mph. Because this recommendation is based on sound but conservative data and predictive expertise, the storage facility is designed in accordance with the recommendation. Those portions of the facility necessary for safety, primarily the storage building, are designed to withstand the DBT's 175 mph winds. The remainder of the facility (the cask receiving area) is designed to withstand a 30 psf wind loading below a 30-ft

Fig. 40 Seismic zone map of the United States.

building height and 35 psf above 30 ft. A tornado generated missile could damage the facility stack, the ventilation fans and ducts, or the cask receiving building. However, missile-generated damage to the fuel storage building itself is not credible. The facility is constructed of thick, heavily reinforced concrete which a windborne missile would not penetrate. Damage to the ventilation system presents no unacceptable hazard. Minor damage can be quickly repaired and major damage can be sufficiently repaired within the available^(a) time period to restore an acceptable cooling-air flow. Major damage repair includes the total replacement of a ventilation fan and housing. Thus, a DBT may cause damage, but it will not result in a safety hazard.

9. LOSS OF COOLANT

A loss of cooling air flow in the storage facility, although a serious situation, would be neither dangerous nor hazardous unless the loss continued for an extended period of time.

A loss of coolant could result from (a) a failure of the cooling air supply and exhaust fans, (b) a loss of both the normal and emergency power systems, or (c) a complete blockage of the inlet and/or outlet ducting or filters. However, to be serious, a loss of coolant must be both complete and permanent, since anything less, as explained in Section VI.5, provides ample time in which to take corrective action before the established fuel temperature upper limit of 1100°F is exceeded.

A complete loss of coolant, however, is considered incredible. The possibility of losing three sets of fans simultaneously, other than a *total* (normal and emergency) power failure, or completely blocking the inlet or outlet duct is negligible. The chance of losing both normal and emergency power, though remote, is possible. Should this occur, ample time (at least 28 hours) is available to take corrective action^(b) before the temperature of the hottest fuel element reaches 1100°F. Thus, a temporary loss of coolant is not considered a hazardous or dangerous condition.

10. FAILURE 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 safely contain the fuel and fission products. Upon a loss of normal power, the emergency generator automatically starts to provide power to the equipment connected to the emergency power bus. Thus, a loss of normal power in no way endangers the facility, the environment, or personnel.

(a) Calculated to be a minimum of 28 hours before fuel centerline temperatures reach 1100°F.

(b) Corrective action might include installing a substitute emergency generator, replacing a fan, or installing a temporary exhaust fan.

11. MECHANICAL FAILURE

All operating equipment is subject to mechanical failure. In designing the Irradiated Fuels Storage Facility, however, extensive efforts were made to provide backup for those systems whose failure could in any way affect the safety of the facility. For example, spares are provided for essential items of operating equipment so that should the operating unit fail, the standby unit will automatically start. In the case of instruments, particularly those indicating radiation levels, sufficient spares are available so that the loss of one unit would not seriously impair the operator's knowledge of facility conditions. In cases where spare units are not available, the equipment is designed so that it can be quickly and easily removed 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 either personnel, the facility, or the environment.

Certain other mechanical failures if coupled with operator error or a series of errors may create handling problems and cause delays. For example, it may be possible, although the chance is remote, to drop a storage canister on top of the storage rack or in the space at the side of the rack. The crane grip switch is protected to prevent inadvertent release of a canister. The crane has limit switches which prevent suspending a canister directly over the open area beside the storage rack. If, however, a canister were dropped in this area, several recovery methods could be used. The 15-ton crane with an auxiliary open hook, possibly could be used to grapple the canister lifting bail. If this method failed, the manipulator could be used to guide the crane hook, using the crane TV for visibility. If this failed, an additional TV camera could be temporarily mounted on the manipulator or crane and an additional grappling device or electromagnet could be used to retrieve the canister. The necessity for this type of an operation is considered very remote. The recovery would not be a routine operation, so no specific equipment has been designed or built for this purpose.

12. DESIGN BASIS ACCIDENT

The Design Basis Accident (DBA) chosen for the Irradiated Fuels Storage Facility is an assumed temporary complete loss of coolant. Even though the possibility of a total loss of coolant is extremely remote (possibly more remote than several of the abnormal occurrences listed in Table XIII), the potential consequences of a lengthy loss of coolant are much more serious than any other abnormal occurrence.

In developing the DBA and the resultant consequences, the following conditions were assumed:

1. Normal fuel storage area cooling air flow through the storage rack is 12,000 cfm

2. all cooling system fans, supply and exhaust become inoperable
3. corrective action can be started within 24 hours
4. the facility is filled with fuel
5. the fuel is stored in steel canisters having tight-fitting lids.

12.1 Fuel Effects

As calculated in Appendix A, the maximum decay heat generated by the stored fuel is approximately 1.2×10^6 Btu/hr. Upon a loss of coolant, the temperature inside the storage facility immediately begins to rise, with the rate of rise directly dependent upon the heat transfer coefficient chosen (the amount of natural convection assumed) and the cooling time assumed for the fuel. For the hottest possible canister of fuel (12 Peach Bottom elements, 120 day cooled), the time required for the temperature of the fuel to reach the conservatively-chosen upper limit of 1100°F varies from 28 hours to several days, as shown in Figure 41, depending on the assumptions used for the calculation^(a). For the fuel storage facility, curves 2, 3, 4, and 5 are assumed to be representative.

The irradiated fuel is stored in 1/4-in.-thick steel canisters having tight-fitting lids. Although graphite begins to slowly oxidize at about 1000°F, air cannot readily reach fuel stored in the above manner, and oxidation, if it occurs at all, would of necessity be slower still. Similarly, although fission products begin to migrate from the fuel at 1000°F, without circulation there is no way for the products to leave the storage can. Thus, unless the loss of forced air cooling continues for an extended period of time (approximately 20 days) and the fuel temperatures reach the melting point of the canisters (approximately 2500°F), a loss of coolant would have a negligible effect on the stored fuel and would cause no significant release of fission products.

The graphite oxidation results discussed above have been substantiated in tests performed at ICPP. During these tests, reactor grade graphite samples were heated for 31 hours at temperatures ranging from 800 to 1400°F. The samples were tested at two test conditions: one open to the atmosphere and the other contained in a closed metal canister representative of a storage canister. The results of the tests are shown in Table XVIII. When the graphite is contained, the effect of temperature is negligible. However, if air is available, oxidation of graphite becomes quite rapid, particularly around 1300°F.

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 (~2500°F) that would be harmful to the storage canisters, at least partial coolant flow could be restored to the storage facility.

(a) The heat of combustion is not included in these calculations. The oxidation of graphite below 1000°F is negligible.

Fig. 41 Temperature of stored fuel as a function of time.

TABLE XVIII

EFFECT OF TEMPERATURE UPON GRAPHITE

Original Sample Weight(g)	Temperature(°F)	Rate of Graphite Weight Loss(g/hr)	
		Open Container	Closed Container
68	800	0.00	-
68	1100	0.05	0.008
70	1200	0.51	-
70	1300	1.90	-
68	1400	2.42	0.007

12.2 Facility Effects

A lengthy loss of coolant in the storage facility could have a potentially more serious effect upon the facility than upon the fuel. Sustained high temperatures can seriously weaken concrete, and cause cracking and spalling. In addition, high temperatures could damage and destroy internal facility equipment including shielding windows, crane, manipulator, crane rails, movable shielding wall, etc. Numerous tests have been performed to determine the effect of temperature upon the properties of concrete. Although 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. Assuming the test results^[28,29] that induced the greatest strength loss with temperature apply to the storage facility, at least 10 days would be available in which to take corrective action before the strength of the storage facility would be significantly reduced. Before temperatures reach these levels, at least partial coolant flow could be restored to the facility.

12.3 Conclusion

Regardless of the circumstances surrounding a loss of coolant, several days (~5, see Figure 41) 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 fans^(a) to obtaining and installing a temporary blower powered by a portable gasoline generator. In addition, corrective action need not restore full cooling. As shown in Figure 41, about 9% of normal flow (1,050 cfm) would be sufficient to keep fuel and facility temperatures below hazardous levels indefinitely.

(a) Two spare fans have been purchased and are located at the storage facility.

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 condition occurring and causing serious consequences is extremely low. All other conceivable accidents are of lesser consequence.

VII. CONCLUSIONS

The Irradiated Fuel Storage Facility will provide safe, dry storage for a number of irradiated graphite-type fuel elements. As designed, the facility can accept fuel from the Peach Bottom, Fort St. Vrain, and Rover reactors and, with a minimum of time and effort, can be adapted to accept and provide storage for fuel from any planned HTGR. The facility is also designed to withstand any natural occurrences postulated for the ICPP area without releasing fission products or causing unacceptable hazards.

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APPENDIX A

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APPENDIX A COOLING SYSTEM DESIGN BASIS

A significant amount of heat will be released by the radioactive decay of the fuel that will be received and stored at the Irradiated Fuels Storage Facility. If not continuously removed, the decay heat could have adverse effects upon both the fuel and the facility. Therefore, the storage facility cooling system has been provided to maintain the centerline temperature of the stored fuel well below the 1100°F arbitrary upper limit.

A-I HEAT GENERATION RATE

The RSAC code was used to calculate the heat generation rate of the Peach Bottom and Fort St. Vrain fuel elements as a function of cooling time. The results of these calculations are shown in Figure A-1. As can be seen, the irradiated graphite fuel elements represent a significant source of heat. As fuel elements are placed in the storage facility, the overall heat generation rate rises steadily as shown in Table A-I. In the eighth year, when the facility is filled with fuel (one core Peach Bottom, 1-1/2 cores Fort St. Vrain), the total heat generation rate reaches a maximum of 1.2×10^6 Btu/hr.

TABLE A-I
HEAT GENERATION RATE

<u>Date of Receipt</u>	<u>Number of Fuel Elements</u>		<u>Total Cumulative Decay Heat (Btu/hr) ^(a)</u>
	<u>Fort St. Vrain</u>	<u>Peach Bottom</u>	
8/76	0	804	5.3×10^5
4/77	240	804	6.0×10^5
4/78	480	804	6.6×10^5
4/79	720	804	7.5×10^5
4/80	960	804	8.3×10^5
4/81	1,242	804	9.9×10^5
4/82	1,482	804	1.0×10^6
4/83	1,722	804	1.1×10^6
4/84	1,962	804	1.2×10^6

(a) Assuming each year's fuel shipment is received 120 days after discharge. Because this is unlikely, these values are conservative. The fuel will probably be 180-day cooled.

Fig. A-1 Heat generation rate as a function of cooling time.

A-II TEMPERATURE PROFILE

Two computer codes, SINDA-3G and CSMP, were used to calculate fuel, canister, and air temperatures as a function of cooling air flow through the facility. SINDA-3G numerically solves the diffusion equation for the thermal analog model presented to it in a network format; CSMP provides a numerical solution to a set of ordinary differential equations describing the model. The basic assumptions used in both codes were:

- (a) The storage facility contains 804 Peach Bottom and 1,962 Fort St. Vrain elements having a total decay heat generation rate of 1.2×10^6 Btu/hr.

- (b) The decay heat is evenly distributed to six equal storage area regions, which are made of 6 rows of positions with 107 canisters per region.
- (c) The fuel is stored in 642 evenly distributed canisters.
- (d) Primary heat transfer is by forced convection air flow exhausted to the environment with secondary heat transfer through the walls and ceiling.
- (e) The inlet air temperature is assumed to be 80°F.

The temperatures calculated by these two codes were almost identical. The results for an "average" fuel canister and the "hottest" fuel canister, assuming cooling air flow of 12,000 cfm, are shown in Table A-II.

TABLE A-II
CALCULATED TEMPERATURES OF STORED FUEL, CANISTERS AND AIR

	<u>Fuel Centerline(°F)</u>	<u>Canister(°F)</u>	<u>Cooling Air (°F)</u>
Average Canister	290	281	180
Hottest Canister	365	353	180

An average canister is defined as the total heat generation rate divided by the total number of canisters; the hottest canister is defined as the canister releasing the greatest amount of decay heat: twelve, 120-day cooled Peach Bottom elements. The approximate heat generation rate from these canisters is 1,640 and 7,920 Btu/hr for the average and hottest canister, respectively.

A plot of fuel and air temperatures as a function of cooling air flow is shown in Figure A-2. As can be seen, temperature decreases rapidly with increasing flow until the flow reaches approximately 8,000 cfm. At flow rates greater than this, the influence of flow upon temperature is markedly reduced so that a large increase in flow is required to obtain a small decrease in fuel temperature. Therefore, an air flow rate of 8,000 cfm is optimum for the storage facility. However, to provide some additional cooling capacity, 12,000 cfm was chosen for the storage rack cooling flow^(a). At a 12,000 cfm flow rate, as can be seen in Table A-II and Figure A-2, the average fuel temperature will be less than 300°F; the hottest fuel temperature will be about 365°F. Graphite oxidation does not occur at temperatures below about 1000°F, so a fuel centerline temperature of 365°F is acceptable.

- (a) The coolant system that is normally in operation provides a flow of 14,000 cfm. However, 2,000 cfm is directed above the storage racks.

Fig. A-2 Fuel temperature as a function of coolant flow, average canister.

A-III SYSTEM DESCRIPTION

The cooling air system is one of the few storage facility systems that should be as failure-free as possible. Therefore, backup fans are provided and the fans are supplied with both normal and emergency power.

The cooling system continually forces 14,000 cfm^(a) of air through the storage facility. Normally, the fuel is enclosed in storage canisters (except during transfer operations) and the cooling air does not directly contact the fuel. A slight possibility exists, however, that radioactive dust and particulate could be released to the air stream. Therefore, prefilters and HEPA filters are installed in the exit air stream to remove essentially all particulate before the air is discharged to the atmosphere through the facility's 65-ft stack.

The design philosophy of all ventilation systems in potentially contaminated areas is to control the release and spread of contamination. Therefore, the air-flow pattern in the storage facility is from uncontaminated areas to areas of higher contamination. In addition, the entire facility except for the control room, is maintained at a negative pressure of about 1/8-in. of water so that any air leakage is into the storage facility.

- (a) The coolant system that is normally in operation provides a flow of 14,000 cfm. However, 2,000 cfm is directed above the storage racks.

APPENDIX B

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APPENDIX B

CRITICALITY CALCULATIONS

Calculations were performed to determine (a) k_{eff} for a number of different fuel storage conditions within the Irradiated Fuels Storage Facility, and (b) whether any potential criticality hazard exists for the recommended fuel handling or storage methods.

The KENO-II computer code with Hansen-Roach 16-group cross sections was used to perform the criticality calculations; thorium cross sections were obtained directly from the Los Alamos Scientific Laboratory, and with the Hemi-KENO code from Oak Ridge National Laboratory.

B-I ASSUMPTIONS

The following assumptions were used as a basis for the criticality calculations:

- 1) The most reactive Fort St. Vrain, Peach Bottom, and Rover fuel assemblies as described in References B-1, B-2, and B-3, respectively, are stored in the facility. (see Section II for description of fuels)
- 2) The uranium loading of the stored elements is on a before-burnup basis, with no credit taken for burnable poison content.
- 3) Evaluation of the handling cave and the dry storage area considered the areas fully loaded with one fuel type for some evaluations and loaded with all three types of fuel for other evaluations.
- 4) Storage canister arrays in the handling cave and the dry storage area are reflected by close-fitting concrete on four sides and the floor, and by the concrete ceiling at its normal location above the array. Uncanned fuel arrays in the handling cave are reflected by close-fitting concrete on two sides and the floor; the other two sides and the ceiling are about 10 ft from the center of the array.
- 5) No hydrogenous moderator is present in the Fort St. Vrain or Peach Bottom fuel arrays; cardboard is present in the Rover array. The cardboard is considered conservatively at a density of 0.9 g/cc. The actual measured density is 0.72 g/cc.
- 6) Fuel storage canisters are 18 in. in diameter, 11 ft high, and fabricated of 1/4-in.-thick steel.
- 7) Rover canister inserts are made of 16-in.-diameter schedule 10 (1/4-in.-thick) carbon steel pipe which hold 15 Rover tubes each in two tiers stacked one above the other approximately 14 in. apart. This results in a total of 30 Rover tubes per canister.

B-II CALCULATIONS AND RESULTS

The specific cases for which criticality calculations have been made and the results of each are outlined below.

1. Case 1

Objective: Calculate the number of elements that can be safely allowed in the handling cave at a given time, and a recommended safe spacing for these elements.

1.1	Conditions	Fuel	Array Size (elements)	k_{eff}
(1)	Uncanned, dry fuel elements. Close packed, partially concrete reflected, square array	Fort St. Vrain Peach Bottom Rover	5 x 5 x 1 5 x 5 x 2 10 x 10 x 1 $\sim 18 \times 19 \times 1^{(a)}$	0.573 $\pm$ 0.010 0.752 $\pm$ 0.009 0.859 $\pm$ 0.014 0.943 $\pm$ 0.012
(2)	Same as (1) except 2 in. edge-to-edge element spacing	Fort St. Vrain Peach Bottom	5 x 5 x 1 10 x 10 x 1	0.466 $\pm$ 0.009 0.434 $\pm$ 0.012
(3)	Canned dry fuel, close-packed, partially concrete reflected, square array	Fort St. Vrain Peach Bottom	4 elements/ storage can- ister ^(b) 20 x 13 x 1 12 elements/ storage can- ister ^(b) 20 x 13 x 1	0.967 $\pm$ 0.009 0.952 $\pm$ 0.010
(4)	All cave floor wells and the shuttle bin containing loaded storage canisters	Rover Rover and Peach Bottom	16 storage canisters in wells and shuttle bin. 30 elements/canister 8 storage canis- ters Rover fuel and	0.309 $\pm$ 0.004 0.292 $\pm$ 0.007

(a) This configuration was an array of 7 x 7 x 1 cardboard tubes reflected as shown in Fig. 35. Each cardboard tube contains 7 Rover elements at 160 g U-235 per element or 1120 g U-235 per cardboard tube, plus excess carbon (density $\rho = 1.9 \text{ g/cm}^3$) to fill a cardboard tube such that $c/x = 143$ ($c/x = c/\text{U-235}$). Calculations at several spacings showed that a close-packed array (no gaps) is the most reactive.

(b) Canisters were 1/4 in. aluminum for this calculation. This is conservative.

1. Case 1 (contd.)

8 storage canisters Peach Bottom
fuel in wells
and shuttle bin:
30 Rover elements/
storage canister
12 Peach Bottom
elements/storage
canister

1.2 Conclusion

There is no hazard in handling the entire contents of a shipping cask of any of the three fuels. The elements are completely safe both in and out of the storage canisters, and in any storage or spacing arrangement. In addition, criticality evaluations have shown that the interaction fractional solid angle with the array shows that there is no interaction hazard for the addition of any one of the following: (a) a loaded Peach Bottom basket, (b) a loaded canister insert, (c) a loaded (J-9 cask) poisoned insert, or (d) the contents of a Rover canister insert spilled on the cave floor.

2. Case 2

Objective: Calculate the potential criticality hazard associated with the fuel storage area containing approximately 636, 18-in.-diameter storage canisters on a 2-ft center-to-center spacing.

2.1	Conditions	Fuel	Array Size (canisters)	k_{eff}
(1)	Dry, concrete reflected tri- angular array.	Fort St. Vrain	30 x 28 x 1 (aluminum canisters)	0.886 ± 0.014
			38 x 17 x 1 (steel canisters)	0.575 ± 0.006
		Peach Bottom	30 x 28 x 1 (aluminum canisters)	0.821 ± 0.009
		Rover ^(a)	11 x 10 x 1 (steel canisters)	0.893 ± 0.010

-
- (a) Each canister contains 2 tiers of elements in canister inserts. Each canister insert contains 20 cardboard tubes. Each cardboard tube contains 8 Rover elements or 1280 g U-235, the $c/\times = 110$.

2.2 Conclusion

The stored fuel is safely subcritical. About 50 percent more fuel than is presently projected for storage in this facility could be safely stored.

3. Case 3^(a)

Objective: Calculate the potential criticality hazard associated with an individual storage canister of each type fuel under several potential accident conditions.

3.1	Conditions	<u>K_{eff}</u>	
		<u>Fort St. Vrain</u>	<u>Peach Bottom</u>
(1)	A dry canister ^(b) surrounded by an infinite water reflector.	0.385 ± 0.006	0.379 ± 0.014
(2)	A water-filled canister ^(b) surrounded by an infinite water reflector.	0.633 ± 0.013	0.796 ± 0.008
(3)	Same as (2) except fuel particles from some of the elements have left the elements and have accumulated in the bottom of the storage canisters ^(b) .	0.661 ± 0.011	0.528 ± 0.011
(4)	Partial water moderation, Rover fuel		
	i) due to humidity	no effect - water volume fraction due to 100% relative humidity at 100°F is <0.00005. WVF at <0.01 has no effect.	
	ii) due to roof leak and water entering canister	if 6.7 liters leaked into a canister insert of Rover Fuel, a criticality hazard exists ^(c) . The water volume fraction would be ~0.1.	

(a) Included simply as an indication of the safety factor associated with these fuels. The conditions postulated are not credible.

(b) Canisters were assumed to be aluminum, 18 in. in diameter, 1/4-in-thick a conservative assumption.

(c) Not considered likely due to tight fit of lid and due to location of canister insert inside canister.

3. Case 3 (contd.)

iii) due to flooding

if the water level reached 7 in. in the storage area^(a) a criticality hazard would exist. That is, as the water started to rise into the fuel bearing portion of the canisters, a criticality could occur.

3.2 Conclusion

There is no criticality hazard associated with a single canister of Fort St. Vrain or Peach Bottom fuel regardless of the conditions postulated. However, a hazard may exist if large quantities of water were to leak into the storage area with Rover fuel present.

4. Case 4

Objective: Determine the affect of storing all three proposed types of fuel in specified regions in the storage area.

4.1	Condition	Fuel	Array Size (canisters)	k_{eff}
(1)	Dry, partially concrete reflected triangular array	Rover Peach Bottom and Fort St. Vrain	(alternating 17 & 18) x 38 x 1 (200 Rover + 75 Peach Bottom, re- mainder Fort St. Vrain ^(b))	0.912 ± 0.006

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- (a) Not considered likely due to locked open floor drain valves, leak tested storage canisters, and the extremely remote chance of a flood entering the storage area.
- (b) The assumptions are that each Fort St. Vrain canister (standard IFSF storage canister) contains 4 elements. Each Rover canister (standard IFSF storage canister) contains 30 cardboard tubes, each cardboard tube contains 7 elements. The average loading of a cardboard tube is 840 g U-235. The cardboard tubes are contained in two 16-in.-diameter carbon steel canister inserts in two tiers inside the canister. Each Peach Bottom canister (standard IFSF storage canister) contains 19 elements (physical maximum - the actual storage condition will be 12 elements per canister). This calculation included the effect of storing Peach Bottom elements at a cut length of approximately 10 ft 6 in. This will include the graphite in the bottom connector, bottom reflector, sleeve, spine, and part of the upper reflector.

A curve of k_{eff} versus Rover U-235 mass is shown in Figure 34.

4.2 Conclusion

There is no criticality hazard associated with storing all three proposed fuel types in the storage area. In addition, due to the small interaction solid angle there is no reactivity affect due to passing a loaded canister over the filled storage rack.

B-III ROVER FUEL

Extensive criticality calculations were also performed for loading procedures at NRDS for the Rover fuel by the Los Alamos Scientific Laboratory (LASL)^(B-4). These calculations were made to determine the maximum safe configuration for these fuel elements assuming several possible fuel element configurations. These configurations and the number of fuel elements required to achieve criticality in each case include:

- (a) A bare accumulation of fuel elements, close-packed would require approximately 2,100 elements.
- (b) Configuration (a) with a thick water reflector would require approximately 1,000 elements.
- (c) If the holes in the fuel elements were flooded, the number of elements required in a close-packed, water-reflected assembly would be about 300.
- (d) If seven elements or the equivalent in pieces were packaged in a 2-3/4-in. O.D. cardboard tube having a 3/32-in. wall, a reflected critical assembly would contain about 220 tubes (1,500 elements).
- (e) If the interstitial volume in configuration (d) were filled with water, the number of tubes required for criticality would be about 40 (280 elements).
- (f) If fuel elements were immersed in water at an optimum spacing, the minimum critical number would be about 40 uncanned, or 50 when in sealed aluminum tubes, based on critical assembly measurements performed at Y-12.
- (g) Five fuel elements at 600 mg/cm³ uranium would contain about 880 grams of U-235. If the material from five elements were essentially homogeneously dispersed as small particles in about 20 liters of water and well reflected, this configuration would be critical. This condition, of course, represents an extreme case.
- (h) A fully-loaded fuel shipping cask: 25 containers each with seven fuel elements. This configuration has a k_{eff} value of <0.3 .

As a result of these calculations, the following conclusions can be made:

- (a) No restrictions need be applied to elements in the existing (Rover) cask inserts.
- (b) Operations with less than 50 intact elements outside the Rover cask inserts present no criticality problem.
- (c) The number of loaded tubes outside inserts and not in a designated storage configuration might appropriately be restricted to about ten.

B-IV REFERENCES

- B-1. Gulf General Atomics, Inc., *Final Design Report for the Fort St. Vrain Fuel Shipping Cask*, GADR-55, Supplement "B" (May 1970).
- B-2. Philadelphia Electric Company, *Application of Philadelphia Electric Company for Construction Permit and Class 104 License, Part C Final Hazards Summary Report, Volume III*, NP-9115 (1963).
- B-3. R. N. Drake, *Preliminary Safety Analysis Report for the Rover Fuels Processing Facility*, ACI-149 (October 1973).
- B-4. USAEC, Nevada Operations Office, *NRDS Fuel Recovery Operations Guide*, NVO-139 (October 1973).

APPENDIX C

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APPENDIX C SHIELDING CALCULATIONS

The source strength of the stored fuel was obtained from Reference C-1 and converted to 180-day cooled. The shielding requirements for the storage facility were calculated using the ISOSHL-D-II^[C-2] computer code.

C-I REQUIREMENTS

The primary shielding requirement for the Irradiated Fuels Storage Facility was that the stored fuel present no radiation hazard to personnel or the environment. As a basis for calculations, the storage facility was divided into areas. A designation was then assigned to each area, depending upon the accessibility of the area and the estimated occupancy time per week. The areas and designations are shown in Table IV, Section III.6.

C-II ASSUMPTIONS AND CONDITIONS

The assumptions upon which the source and shielding calculations were based included the following:

- (1) The storage facility was filled with irradiated fuel.
- (2) The most radioactive fuel was stored in the facility, i.e., 180-day cooled Fort St. Vrain fuel.
- (3) The stored fuel was obtained from a 6-yr equilibrium core having a burnup of 100,000 MWd/tonne.
- (4) Ordinary concrete was used for shielding.

In addition, in the calculations, no credit was taken for the rebar, the 3/8-in.-thick can lid, the height of the facility roof, or the fact that the initial fuel shipments will only be irradiated to 17,000 MWd/tonne.

All of the above assumptions lead to conservative results, and thus under no conditions could the radiation levels be greater than the calculated values.

C-III RESULTS

The source data for each storage canister (4 elements) is presented in Table C-I.

TABLE C-I

SOURCE DATA FOR ONE FUEL STORAGE CANISTER
(180-day cooled, Fort St. Vrain Fuel)

<u>Isotope</u>	<u>Curies</u>
Y-91	13,400
Zr-95	17,000
Nb-95m	90
Nb-95	32,440
Ru-103	1,924
Rh-106	4,160
Ba-137m	12,400
Ba-140	8
La-140	8
Ce-144	62,000
Pr-144	62,000

Based on the source data of Table C-I, the ISOSHL-D-II code was used to compute the surface dose rate at the walls of the facility as a function of wall thickness and the surface dose rate at the roof of the facility as a function of the roof thickness. The wall and roof calculations are presented in Figures C-1 and C-2, respectively. Figure C-2 also presents the estimated dose rate at ground level, assuming an albedo value of 0.1%. These figures were then used to determine the wall and roof thicknesses required to reduce the external radiation levels to acceptable values (see Section III.6).

C-IV REFERENCES

- C-1. Gulf General Atomic, Inc., *Final Design Report for the Fort St. Vrain Fuel Shipping Cask*, GADR-55 (April 1969).
- C-2. R. L. Engel, et al, *ISOSHL-D-A Computer Code for General Purpose Isotope Shielding Analysis*, BNWL-236 (June 1966).

Fig. C-1 Surface dose, storage facility walls.

Fig. C-2 Surface dose, storage facility roof.

APPENDIX D

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APPENDIX D

George L. Voelz, M. D., Director February 14, 1968
Health Services Laboratory
Thru: Charles A. Pelletier
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PLUTONIUM DOSE CRITERIA FOR REACTOR SAFETY ANALYSIS

Presently two dose criteria are used to evaluate, for design purposes, the consequences of the so-called maximum credible accident (MCA) for a reactor installation. These criteria are:

- (i) The whole body dose to a person in an unrestricted area must not exceed 25 rem, and
- (ii) the total dose delivered to the thyroid of a person in an unrestricted area must not exceed 300 rem^[1].

These criteria must be applied to the critical group within the population at risk. The limits are not acceptable doses to the public in an emergency situation.

The probability is small that observable damage to the health of the recipients of such doses would occur. Calculations based on the results presented by a Task Group of Committee I of the International Commission on Radiological Protection (ICRP)^[2], which examined the risks of radiation exposure, result in the following conclusions:

- (i) The probability that an individual receiving a whole body dose of 25 rem will develop leukemia as a result is about 5×10^{-4} , and
- (ii) the probability that an individual receiving a whole body dose of 25 rem will develop any other form of cancer as a result is about 5×10^{-4} , and
- (iii) the probability that an individual receiving a dose of 300 rem to the thyroid will contract thyroid cancer as a result is about 6×10^{-3} .

From the point of view of the whole population, the average number of cases of a given type of cancer induced in the population per reactor-year as the result of receiving a specified dose is the product of:

- (i) The probability that the accident will occur,
- (ii) the number of individuals in the population who receive the specified dose as the result of the accident, and

- (iii) the probability that an individual who receives the specified dose will contract the given type of cancer.

Dose criteria for accidental exposure of the general population to plutonium-239 are needed to evaluate the consequences of the MCA's for proposed fabrication facilities, critical facilities, and reactors which could release significant quantities of plutonium-239 to the environment as a result of the MCA. The dose criteria recommended for exposure to plutonium-239, in unrestricted areas, as the result of a MCA are:

- (i) 100 rem for the total dose delivered to the lung,
- (ii) 150 rem for the total dose delivered to the bone, and
- (iii) 100 rem for the total dose delivered to the liver.

The critical organ for such an exposure depends upon the chemical and physical nature of the plutonium-239 to which the population is exposed.

The report of the ICRP Task Group states that the dose response data for bone sarcoma and lung or liver carcinoma induction in humans which are currently available are not sufficient to justify the extrapolation to moderate and low dose situations. As a result, the Task Group has made no numerical estimate of the risk of contracting these cancers. The dose criteria recommended above are based on the examination of human and animal data^[3-8]. It is believed that the probability of inducing a lung or liver carcinoma or bone sarcoma in an individual receiving a dose equal to the appropriate dose criterion is no longer than the probability for inducing a cancer as the result of a whole body dose of 25 rem, i.e., 1×10^{-3} . The dose criteria recommended for plutonium-239 are believed, therefore, to be consistent with the dose criteria presently established.

It is recommended that the report of the Task Group on Lung Dynamics of the ICRP^[9] be used as the basis for calculating doses to the various organs and tissues resulting from inhalation of a plutonium-239 aerosol. A report on the utilization of the models proposed by the Task Group is being prepared.

A single inhalation of some forms of plutonium-239 will result in significant doses to more than one organ or tissue, and the result may be comparable to that of whole body exposure. This problem is discussed briefly in ICRP Publication 9^[10], which states that a precise evaluation of the situation is not possible at this time. It is apparent that the critical group in the exposed population will be young children. In addition to the more or less quantifiable variables of organ or tissue area and effective radius, there are other factors which complicate the dose computation. These include metabolic differences and increased radiosensitivity of proliferating cells, the numerical assessments of both of which are presently not familiar.

REFERENCES

1. Title 10, Code of Federal Regulations, Part 100.
2. "The Evaluation of Risks from Radiation": A report prepared by a Task Group of ICRP Committee I, *Health Physics*, 12, 239-302 (1966).
3. G. L. Voelz, Trip Report: Delayed Effects on Bone-Seeking Radionuclides Conference, Sun Valley, Idaho, September 12-14, 1967.
4. R. Censer, "Radiogenic Lung Cancer", in *Progress in Experimental Tumor Research*, Vol. 4, pp 251-303, Karger, Basel/New York (1964).
5. *Radiological Health and Safety in Mining and Milling of Nuclear Materials*, Vol. 1, International Atomic Agency, Vienna (1964).
6. J. S. Robertson and S. H. Cohn, "Evaluation of Plutonium Exposures in Man", BNL-7041 (1963).
7. *Radiation Exposure of Uranium Miners*, U. S. Government Printing Office, Washington (1967).
8. "Proceedings of the Hanford Symposium on the Biology of the Transuranic Element", *Health Physics*, 5, 561 (1962).
9. "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract": A report prepared by a Task Group of ICRP Committee II, *Health Physics*, 12, 173-207 (1966).
10. Recommendations of the International Commission on Radiological Protection (1965), *ICRP Publication 9*, Pergamon Press, Oxford (1966).

APPENDIX E

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APPENDIX E

E-I DOSE CALCULATIONS

The off-site doses that might be expected from accidents involving the graphite fuels were calculated using Equation (E-1).

$$\text{Dose} = \text{Source} \times \text{DCF} \times \frac{\chi}{Q} \quad (\text{E-1})$$

where

$$\begin{aligned} \text{Dose} &= \text{the receptor dose, rem} \\ \text{Source} &= \text{the quantity of nuclide released, curies} \\ \text{DCF} &= \text{inhalation exposure conversion factor,} \\ &\quad \text{rem m}^3/\text{Ci sec.} \\ \frac{\chi}{Q} &= \text{axial concentration at receptor location, sec/m}^3 \end{aligned}$$

Because the value of χ/Q is a function of the weather existing at the time of release, a χ/Q value was calculated for each weather class (A through F), and for a Class F fumigation condition. The most conservative value for the off-site doses resulted from the Class F fumigation condition, and this value was used in the off-site dose calculations. The values calculated for each condition are shown in Table E-1.

TABLE E-1

χ/Q FOR OFF-SITE AS A FUNCTION OF METEOROLOGICAL CONDITIONS

<u>Condition</u>	<u>χ/Q (sec/m³)</u>
A	3.8×10^{-9}
B	1.73×10^{-8}
C	4.74×10^{-8}
D	9.3×10^{-7}
E	2.8×10^{-6}
F	3.6×10^{-6}
Fumigation	7.8×10^{-6}

The on-site doses were calculated in the same manner as the off-site doses. The most conservative χ/Q (5.45×10^{-4}) was obtained from a Class F fumigation condition at a downwind distance of 100 meters using a stack release model.

Use of the stack release model is preferred over use of the building wake model. Calculations of doses using the building wake model require the assumption that the release

occurs at ground level. The actual release point, however, would be from a stack outlet that is 65 ft above ground level. The normal "rules of thumb" which should be met to avoid the effect of building turbulence are (a) The stack height should be at least 2.5 times the height of adjacent buildings (or approximately 88 ft high), and (b) The stack velocity should be at least 1.5 times the average wind speed during unstable conditions. Using the methods in Reference E-2, an effective stack height of 119 ft was calculated. This includes the effects of stack velocity and outlet air temperature. The effect of the relatively short actual stack height would tend to be balanced by the effect of the high stack velocity and resulting higher effective stack height. Thus, it is reasonable to use the X/Q values calculated for a 65-ft stack in determining the on-site doses tabulated in Table E-II.

If the building wake model were used, the X/Q for the on-site dose calculations would be 3.27×10^{-4} which would yield doses lower than those shown in Table E-II. The off-site doses calculated using the building wake model are not significantly different than those using the stack release model. The X/Q would be 8.1×10^{-6} versus 7.8×10^{-6} which was actually used for Table E-II. In either case, the doses are well within the off-site dose limits.

Using the source values shown in Tables XV and XVI, the on- and off-site receptor doses were then calculated using the RSAC computer code. A summary of the results of the calculations is shown in Table E-II. This table lists the isotope and the on- and off-site doses for both body and bone. Doses for other organs (lungs, thyroid, liver, etc.) were also calculated, but none were significant when compared to the body and bone doses. The doses shown in Table E-II are the total doses that would be received from the complete release of all the isotopes from one fuel element. The actual doses were obtained by reducing the total dose by 10^{-4} which accounts for 1% of the particles having fractured ratings, and 1% of the solids being released.

The 1% release fraction was based on the guidelines of TID-14844^[E-2]. Although TID-14844 is intended for fuels in a pressurized water reactor, melting and fission product release experiments^[E-3, E-4, E-5, E-6, E-7] with dry fuels indicate that the TID-14844 values are very conservative. With the exception of the SNAPTRAN test, all experiments have shown that the solids released from fuel meltdown experiments have been found to be much less than 1%, except for Cs and Te, which have ranged as high as 50%. Approximately 4% of the solids were released from the fuel during the SNAPTRAN tests. However, this test was much more severe than anything that could be experienced in the storage facility in that the fuel was pulverized by the test and then burned as it was disbursed through the atmosphere. As mentioned, however, even this extreme case did not cause a large solids release. Thus, based on the results of the referenced test, an assumption of 1% solids release is believed to be conservative.

Just for comparison, off-site doses have been calculated assuming a 4% solids release. The doses for an entire shipment of fuel are 0.17 and 5.45 rem, body and bone, respectively, for Fort St. Vrain and 0.055 and 1.6 rem for Peach Bottom; all still well below acceptable limits.

TABLE E-II
CALCULATED RECEPTOR DOSES

Isotope (a)	Source(curies)		Dose(rem) off-site		Dose(rem) off-site		Dose(rem) on-site	
			All Release		Actual		Actual	
	Fort St. Vrain	Peach Bottom	Body	Bone	Body	Bone	Body	Bone
Sr-89	3928		1.25×10^{-1}	4.45	1.25×10^{-5}	4.45×10^{-4}	8.73×10^{-4}	3.11×10^{-2}
Sr-90	3170		2.04×10^1	3.31×10^2	2.04×10^{-3}	3.31×10^{-2}	1.43×10^{-1}	2.31
Y-91	4506		1.1×10^{-1}	4.15	1.1×10^{-5}	4.15×10^{-4}	7.69×10^{-4}	2.9×10^{-2}
Zr-95	6160		2.7×10^{-1}	1.04	2.7×10^{-5}	1.04×10^{-4}	1.89×10^{-3}	7.3×10^{-3}
Nb-95	11,941		1.46×10^{-1}	4.3×10^{-1}	1.46×10^{-5}	4.3×10^{-5}	1.02×10^{-3}	3×10^{-3}
Cs-137	3210		2.85×10^{-1}	5.32×10^{-1}	2.85×10^{-5}	5.32×10^{-5}	1.99×10^{-3}	3.72×10^{-3}
Ce-141	1904		8.55×10^{-3}	1.03×10^{-1}	8.55×10^{-7}	1.03×10^{-5}	5.96×10^{-5}	7.2×10^{-4}
Ce-144	14,849		2.64	4.86×10^1	2.64×10^{-4}	4.86×10^{-3}	1.84×10^{-2}	3.4×10^{-1}
Pm-147	6080		1.16×10^{-1}	3.14	1.16×10^{-5}	3.14×10^{-4}	8.11×10^{-4}	2.19×10^{-2}
Pu-238	119		4.64×10^1	1.86×10^3	4.64×10^{-3}	1.86×10^{-1}	3.26×10^{-1}	1.3×10^1
Pu-241	48		3.3×10^{-1}	1.65×10^1	3.3×10^{-5}	1.65×10^{-3}	2.34×10^{-3}	1.16×10^{-1}
Σ			7.08×10^1	2.27×10^3	7.08×10^{-3}	2.27×10^{-1}	4.97×10^{-1}	1.59×10^1
Sr-89		1170	3.7×10^{-2}	1.33	3.7×10^{-6}	1.33×10^{-4}	2.59×10^{-4}	9.3×10^{-3}
Sr-90		393	2.52	4.11×10^1	2.52×10^{-4}	4.11×10^{-3}	1.76×10^{-2}	2.87×10^{-1}
Y-91		1725	4.18×10^{-2}	1.58	4.18×10^{-6}	1.58×10^{-4}	2.92×10^{-4}	1.1×10^{-2}
Zr-95		2090	9.12×10^{-2}	3.54×10^{-1}	9.12×10^{-6}	3.54×10^{-5}	6.37×10^{-4}	2.47×10^{-3}
Nb-95		3980	4.94×10^{-2}	1.43×10^{-1}	4.94×10^{-6}	1.43×10^{-5}	3.45×10^{-4}	1×10^{-3}
Cs-137		600	5.33×10^{-2}	1.01×10^{-1}	5.33×10^{-6}	1.01×10^{-5}	3.72×10^{-4}	7.06×10^{-4}
Ce-141		635	2.85×10^{-3}	3.42×10^{-2}	2.85×10^{-7}	3.42×10^{-6}	2×10^{-5}	2.39×10^{-4}
Ce-144		5060	9.04×10^{-1}	1.67×10^1	9.04×10^{-5}	1.67×10^{-3}	6.32×10^{-3}	1.17×10^{-1}
Pm-147		1500	2.85×10^{-2}	7.8×10^{-1}	2.85×10^{-6}	7.8×10^{-5}	2×10^{-4}	5.45×10^{-3}
Pu-238		9.5	3.71	1.5×10^2	3.71×10^{-4}	1.5×10^{-2}	2.6×10^{-2}	1.04
Pu-241		20	1.4×10^{-1}	6.9	1.4×10^{-5}	6.9×10^{-4}	9.7×10^{-4}	4.8×10^{-2}
Σ			7.85	2.19×10^2	7.6×10^{-4}	2.2×10^{-2}	5.3×10^{-2}	1.52×10^0

(a) Only those isotopes that contribute to the total dose are included in the table.

E-II. REFERENCES

- E-1. G. R. Yanskey, et al, *Climatology of the National Reactor Testing Station*, IDO-12048 (January 1966).
- E-2. J. J. DiNunno, et al, *Calculation of Distance Factors for Power and Test Reactor Sites*, TID-14844 (March 1962).
- E-3. Convair, *Fission Products Field Release Test - 1*, ANP Doc. No. NARF-59-32T (September 1959).
- E-4. Convair, *Fission Products Field Release Test - 2*, ANP Doc. No. NARF-60-10T (September 1960).
- E-5. W. A. Freeby, et al, *Fission Product Behavior Under Simulated Loss-of-Coolant Conditions in the Contamination-Decontamination Experiment*, IN-1172 (January 1969).
- E-6. W. E. Kessler and L. N. Weydert, Jr., eds., *SNAPTRAN-2 Destructive Test Results*, IDO-17194 (January 1967).
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APPENDIX F

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APPENDIX F

SAFETY ANALYSIS REPORT BASES

A. SAFETY LIMITS – VIOLATION REQUIRES ERDA AND ALLIED CHEMICAL CORPORATION MANAGEMENT NOTIFICATION

1. Reduction of cooling air flow to less than 1,000 cfm shall not exceed 48 hours when Peach Bottom fuel or Fort St. Vrain fuel is stored. (SL&R#III.6-2)
2. Each and all of the following limits shall apply to Rover fuel loading. (SL&R#III.6-2)
 - (a) The fuel shall not be stored if the contents of a cardboard tube exceeds either:
 1. 1120 grams U-235 per cardboard tube.
 2. 6 kg of fuel mixture net weight.
 - (b) The contents of a canister insert shall not exceed either:
 1. 15 tubes per canister insert.
 2. 12.6 kg U-235 per canister insert.
3. No moderator, other than that which is a part of specifically approved fuel elements or storage canisters, is permitted in the fuel handling cave or fuel storage area when fuel is present. (SL&R#III.6-3)

Exception 1: Two people are permitted in the handling cave with a maximum of 42 cardboard tubes of Rover fuel in the cave subject to each of the following conditions:

- (a) a maximum of 5 kg U-235 may be permitted outside of a cask insert or a cave floorwell.
- (b) only one tube at a time may be removed from the cask insert or the canister insert.

Exception 2: A plastic covering over the Rover cask and lid is permitted in the handling cave, subject to the following condition: Plastic must be attached to the cask and lid and must not be in the cave during fuel removal from the poisoned Rover cask insert.

B. SAFETY REQUIREMENTS – VIOLATION REQUIRES ERDA AND ALLIED CHEMICAL CORPORATION MANAGEMENT NOTIFICATION

1. No water is allowed in the fuel handling cave or fuel storage area when any fuel is present. (SL&R#III.6.1-1)
2. Only one fuel element or cardboard tube may be handled at one time in the handling cave, and only one type of fuel may be stored in each cave floorwell. (SL&R#III.6-4)
3. Store Rover fuel only in Rover zone. (A through K, A' through K' rows 16 through 35 for a total of 200 positions.) (SL&R#III.6.6-1)
4. Rover fuel may only be placed in the following positions: (SL&R#III.6.1-3)
 - (a) In canister inserts in canisters in any or all cave floorwells.
 - (b) In canister inserts in canisters in the shuttle bin or on the crane.
 - (c) In only one of the canister inserts on the pedestal.
 - (d) In the poisoned cask insert.
 - (e) Being transferred between these positions or to the storage area.
5. The following conditions must be met prior to introducing Rover fuel into the fuel handling cave when Peach Bottom fuel is present. (SL&R#III.6.1-4)
 - (a) All intact Peach Bottom fuel elements (still in shipping canisters) must be placed in a shipping basket in a cave floorwell.
 - (b) All cut Peach Bottom fuel elements must be in canisters with lids in place in cave floorwells. All pieces of cans and inert end pieces of elements must be in cut-piece containers.
 - (c) Prior to resumption of handling and cutting of Peach Bottom fuel, the Rover cask insert must be unloaded; and fully loaded Rover canisters must be transferred to a cave floorwell or to the storage area, and all loaded or partially loaded Rover canister inserts must be placed in a canister in a cave floorwell.
6. Store Peach Bottom fuel only in the Peach Bottom zone. (L through U, L' through T', rows 26 through 75 positions.) (SLL'R#III.6.2-1)
7. Peach Bottom fuel may only be placed in the following positions: (SL&R#III.6.2-1)
 - (a) In canisters or baskets in cave floorwells.

- (b) In a canister in the shuttle bin or on the crane.
 - (c) On the saw.
 - (d) In the cask in the transfer car.
 - (e) Being transferred between these positions or to the storage area.
8. The following conditions must be met to permit Peach Bottom fuel to be introduced into and handled in the fuel handling cave while Rover fuel is still present in the cave. (SL&R#III.6.2-3)
- (a) Rover fuel unloading operations must be stopped.
 - (b) All Rover fuel, except that still in the poisoned cask insert, must be placed in a canister (in canister inserts) in a cave floorwell and lid must be on the canister.
 - (c) The shipping basket of Peach Bottom fuel must be placed in a cave floorwell before unloading of the Rover cask insert can be resumed.

C. STANDARD OPERATING PROCEDURE REQUIREMENTS – VIOLATION OR INABILITY TO MEET REQUIREMENTS REQUIRES SHIFT SUPERVISOR OR AREA SUPERVISOR NOTIFICATION

- 1. Operator must check the storage facility at least once per day. (The operator should check for proper operation of the cooling air system, for unexpected high radiation levels as shown on the radiation instruments and that the instruments are operating properly. Other checks will be performed as specified by the Storage Facility Supervisor.)
- 2. Daily visual check must be made of the fuel storage area and handling cave for water and a weekly check of the drain system and sump for water.
- 3. Storage area and handling cave floor drain valves must be kept locked open to prevent accumulation of water.
- 4. Only standard IFSF storage canisters may be used for fuel storage.
- 5. Shipping cask seals will not be broken outside of the handling cave unless a cask sample shows no detectable fission products.
- 6. Only one type of fuel may be stored in each canister.
- 7. Broken elements must be stored in canisters with dust tight lids, and must be stored in the same region as whole-element canisters of that fuel type.

8. Net weight of fuel in broken element canisters must be recorded after each addition of fuel. Canisters limited to two equivalent Fort St. Varin or eight equivalent Peach Bottom elements.
9. Only one canister of fuel is allowed outside an authorized temporary or permanent storage position (storage area position, cave floorwell or shuttle bin), at a time in the fuel handling cave and fuel storage.
10. Only one storage canister containing fuel is allowed to be open at a time in the fuel handling cave, to minimize mixing of fuel types and to aid in maintaining accountability.
11. Only one fuel element or one tube of Rover fuel at a time may be handled outside a shipping container, canister insert or storage canister.
12. No combustibles other than those approved for storage are permitted in non-fire-protected areas when fuel is present. Plastic may be used to cover casks for contamination control. Fuel handling not permitted while plastic is present.
13. No cutting operation is allowed unless vacuum is operating properly, with filter in place, and suction is directed to the saw pickup head, i.e., the vacuum diverter valve is in the proper position.
14. Fuel element cutting is limited to nonfueled sections only.
15. Individual fuel element handling or cutting operations are not allowed while a cask is in the handling cave.
16. Manipulator is to be used in fuel storage area only when authorized by area supervisor.
17. A monthly test operation of emergency generator is required to ensure operational readiness, and full-load test every six months is required.
18. Monthly test operation of nonoperating H&V fans is required.
19. Facility door keys are to be kept under control by Operation Supervisor and doors to crane maintenance area and shielding-door enclosure kept locked except when access is authorized by area supervisor.
20. Fuel to be stored must be at least 120-day cooled or an evaluation of heat generation rate made prior to acceptance of fuel.
21. Portable fire extinguishers will be available in the control room and crane maintenance area and near the door to the emergency generator room and/or other appropriate areas.

22. Entrance doors and other appropriate locations will be posted with the fire fighting requirements. (No water is permitted in either handling cave or storage area.)
23. All control instruments, radiation instruments and equipment will be included in the appropriate PM schedule.
24. The crane will be positioned out of the fuel storage area or away from the high radiation areas when fuel is not being handled.

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