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HOT FUEL EXAMINATION FACILITY/NORTH
FACILITY SAFETY REPORT

Argonne-West

Idaho National Engineering Laboratory

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HOT FUEL EXAMINATION FACILITY/NORTH FACILITY SAFETY REPORT

PREFACE

This report supersedes the HFEF/N Interim Facility Safety Report and the "Approval Copy" of the HFEF/N "Final Facility Safety Report." It includes an evaluation of the safety of proposed operations to be carried out in HFEF/N in the foreseeable future, including both destructive and non-destructive examinations of irradiated capsules, elements and loops. The safety of operations involving the Sodium Loop Safety Facility will be covered in a separate addendum to be submitted later.

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ABSTRACT

This report describes the design and safety-related construction features of the Hot Fuel Examination Facility/North, located on the Argonne-West site at the Idaho National Engineering Laboratory. The proposed operations, the organizational structure, and emergency plans are described. Evaluations of potential accident situations are presented and it is concluded that HFEF/N can be operated safely and without undue hazard.

SECTION I
FACILITY DESCRIPTION

I. FACILITY DESCRIPTION

A. Cell Complex

1. Introduction

The Hot Fuel Examination Facility/North (HFEF/N) is a hot-cell complex for the preparation and examination of irradiation experiments in support of the Liquid Metal Fast Breeder Reactor (LMFBR) program. A wide range of remote operations and examinations may be performed in this facility with its modern cells, support areas, and equipment.

Two important aspects of the LMFBR program are (a) the development of high-burnup fuel elements and (b) the advancement of knowledge of fuel-related safety characteristics. Generally, the materials examined in the HFEF/N to support fuel and structural material development will have been irradiated in the EBR-II reactor. To support the LMFBR safety programs, HFEF/N will be used for preparing test specimens and examining loop experiments that have been irradiated in the Transient Reactor Test Facility (TREAT), the Engineering Test Reactor (ETR), or the Power Burst Facility (PBF). Also, irradiated materials from other programs and facilities may be accommodated.

The HFEF/N consists primarily of two adjacent shielded cells--the Main Cell and the Decon Cell--in a three-story building as shown in Figs. I-1 through I-7. Offices, laboratories, and other personnel-related areas are

Fig. I-1. Cutaway Diagram of the HFEF/N

Note: 6-inch wide load path for CG of loads greater than 20 T.

Fig. I-2. Elevation Sections of the HFEF/N. ANL Neg. No. 103-12470 Rev. 1.

Fig. I-3. Elevation Section of the Cells. ANL Neg. No. 103-12472.

Fig. I-4. Plan of the Service Floor. ANL Neg. No. 103-12989 Rev. 1.

Fig. I-6. Plan of the Second Floor. ANL Neg. No. 103-12990 Rev. 1.

Fig. I-7. Plan of the High-bay Area. ANL Neg. No. 103-A12231 Rev. 2.

located on the operating floor, which is slightly above grade level. A truck lock at the west end of the cell complex is also at this level. The service floor below contains the subcell tunnels and most of the building equipment. The second floor contains additional building equipment, the DAPCS computer room, and offices.

A high-bay area covering the entire cell complex and serviced by a 50-ton bridge crane provides access to the tops of the cells for bottom-opening casks. This area contains the repair rooms, change room, and access room, and provides space for clean equipment repair and mockup, and cask storage.

The facility is designed so that it can be adapted to future programs. Examination, general-purpose handling, and service equipment can be changed remotely or supplemented without major interruptions of the operations in progress. This feature will make it practical to update equipment as the technology develops. The facility also includes built-in expansion capabilities in the form of unequipped work stations, which can be activated with only temporary interruption of normal operations.

2. Main Cell Configuration

The heart of the facility is the Main Cell where most examinations are carried out. The cell is 30 x 70 x 25 ft high inside, with a steel floor that can be removed to provide access to a recessed area about 8 ft deep x 30 x 40 ft. The space beneath the removable floor is used for shielded radioactive sample storage, equipment storage, and inert-gas return ducts and filters; it also provides additional space for vertical handling of long items. At two of the work stations there are 33-in. nominal inside diameter steel-lined pits extending 30 ft below the level of the removable floor for vertical positioning of long loops. Two setbacks on the north and south walls (see Fig. I-2) support the rails for the electromechanical manipulators and the five-ton cranes. The walls of the Main Cell are 48-in.-thick, 3.5-sp-gr concrete (220 lb/ft^3) up to a height of about 14 ft above the operating floor. Above this height the cell walls and the cell roof are 48-in.-thick, 2.3-sp-gr concrete (147 lb/ft^3). The walls are lined with a gastight steel liner capable of containing a high-purity argon atmosphere. Penetrations into the cell are also steel lined and welded to the cell liner. Closures or inserts for these penetration liners are gastight and have double seals with the space between them pressurized with fresh argon.

The Main Cell has 15 work stations, each 10-ft wide, which can be equipped with a pair of manipulators, a shielding window, lights, a utility distribution system, examination equipment, and suitable work tables. A few work stations are equipped with specific-purpose ports for periscopes, stereomicroscopes, and gamma-scanning equipment. Work stations that are not provided with examination equipment at startup can be fitted with

sealed and plugged ports for utilities. These items can be added later without releasing radioactive contaminants, polluting the cell atmosphere, or extensively interrupting work at adjacent stations.

For fuel material storage, ten pipes (storage pits), each 12 inches in diameter and 10 ft deep, are located in the floor of the center aisle. All of these pipes are connected to an argon cooling system for subassembly storage and all pipes will be provided with fuel storage inserts. Steel shielding plugs are installed at the bottoms of the cooled pipes to reduce the radiation levels in the subcell area.

Metallurgical samples are stored in one of the Main Cell storage pits and in the metallograph room. Special containers will be used in these storage pits to avoid criticality problems. No cooling is required for sample storage, and progressive buildup of radioactive debris is prevented by dry vacuuming the pipes whenever necessary. Hatch covers over the pits minimize the need for vacuuming.

The Main Cell is designed to handle both contained and uncontained sources in a single large cell rather than in separate ones. Measures will be taken to minimize the particulate contamination of experiments and the radioactive contamination of equipment that must be serviced by contact. These measures will include the local containment of operations generating large quantities of particulate material, and filtration and uniform distribution of the recirculating argon atmosphere. The advantages of the single large-cell concept include a capability for handling large loops and associated equipment, and the adaptability to future programs by the rearrangement of examination equipment.

3. Main Cell Manipulators and Material-handling System

Sealed master-slave manipulators are installed at work stations for many of the operations required for the examination work.

A dual-level overhead system is provided to carry out handling tasks beyond the reach or capacity of the master-slaves. This system, shown in Fig. I-3, consists of two 5-ton cranes on the upper level rails and two telescoping-tube electromechanical (E-M) manipulators on the lower level rails. Each E-M manipulator is rated for lifting 750 lb and has a vertical travel of approximately 11 ft 9 in. The lower end of each telescoping tube is fitted with a parallel-jaw tong or a double closable hook to grip and rotate equipment, tools, and supplies about a vertical axis. An articulated E-M manipulator can also be attached to the lower end of each telescoping tube.

A small cart, running on rails below the windows and close to the walls inside the cell, is provided to transport materials, tools, fuel samples,

and small equipment from one work station to another. Two gas-lock penetrations (see Section I.A.9) permit the transfer of small, nonradioactive items directly into the Main Cell without polluting the cell atmosphere or releasing contaminants. These penetrations enter the Main Cell at work stations 1M and 15M where the master-slave manipulators can be used to load the interstation cart with materials for work stations throughout the cell. A small vacuum lock in the wall between the Main Cell and the Decon Cell provides a direct route for transfer of materials between these cells.

4. Main Cell Shielding Windows and In-cell Lights

Combination oil-and-glass windows provide shielding approximately equal to that of the walls. Each window is composed of five glass slabs with thin layers of oil between them, plus a protective glass plate on the in-cell side. This protective plate is supported by a frame hinged from the liner so that it can be swung into the cell for cleaning or replacement by means of the remote handling equipment.

The window assembly is 64 in. wide by 44 in. high on the in-cell side, including the protective plate, tapering to 40 x 24 in. on the operator's side. The thicknesses of the components of the window assembly, from inside out, are as follows:

- 2 in. glass, density 2.53
- 1/2 in. argon (air in Decon Cell windows)
- 9 in. glass, density 2.53
- 4 1/2 in. oil
- 8 in. glass, density 3.23
- 1/8 in. oil
- 9 in. glass, density 3.23
- 1/8 in. oil
- 11 1/2 in. glass, density 5.20
- 3 in. oil
- 3/4 in. glass, density 2.53

The in-cell side of the window tank is sealed by a 9-in.-thick glass slab, which provides radiation protection for the oil-seal gaskets.

The efficient performance of remote hot-cell operations is aided considerably by the proper distribution of high-intensity lighting. Experience with existing hot cells indicated that an "as-viewed" illumination level

(product of the in-cell level and the window transmittance) of 100 to 150 lm/ft² on a vertical plane 3 ft from the window is satisfactory for most examination work. This general level is provided by remotely replaceable luminaires with 400-W mercury-vapor lamps at each active work station. Additional luminaires are installed in other areas in the cell for general lighting. Emergency lighting, which starts instantaneously, is provided by tungsten-iodine lamps to give an as-viewed level of about 10 lm/ft².

5. Main Cell Electrical and Pneumatic In-cell Service

Each active work station is provided with a variety of electrical and pneumatic (argon) services. The electrical services include multiple supply circuits for 115-V and 240-V A.C. power, power lines from the lighting ballasts, about 100 conductors for various control functions, and about 50 instrument lines (not all stations). The power circuits are controlled from a wall-mounted panel outside the cell, and terminate in receptacles on vertical panels on both sides of each work station. These in-cell utility panels are positioned so they can be reached with the mechanical master-slaves. The control and instrument lines terminate at receptacles on these same panels both inside and outside the cell so that a variety of equipment, each with its own control console, can be interconnected. A gas distribution system is also provided at each active station to power and control pneumatically-operated tools and equipment. Quick-disconnect couplings are provided at the in-cell utility panels.

6. Main Cell Argon System

The Main Cell contains a high-purity argon atmosphere of 65,000 ft³ at startup (see Section I.B.2). The gas recirculates through a high-volume cooling system (about 14,000 cfm) and HEPA filters. Part of this flow is also passed through carbon filters to remove iodine. A small portion of the gas flow passes through a purification system to remove oxygen and water vapor to nominal levels of 25 and 50 ppm, respectively. The nitrogen concentration is controlled by exhausting the cell gas and replenishing it with fresh argon. The Main Cell atmosphere is maintained at a nominal reduced pressure (-1.0 to -4 in. water gauge).

All flanged penetrations into the Main Cell (except the large equipment in-cell transfer lock; see I.B.3.b) are double sealed and have leak detection capabilities.

7. Decon Cell

The Decon Cell has six work stations. Some are utilized for the decontamination of equipment, irradiated components, and loop hardware. Others are used for transfers and for future projects. The loop decon station is a nonequipped station, but it can be activated without a great deal of interference with normal cell operations.

The Decon Cell is separated from the Main Cell by a shielding wall of 48 in. of 2.3-sp-gr concrete. This cell is the same width and height as the Main Cell and its outer walls are shielded in the same manner. The cell floor is lined with stainless steel and the walls are lined with carbon steel coated with an epoxy paint to a height of 13 ft 6 in. above the cell floor.

The work stations in the Decon Cell are the same size as those in the Main Cell.

The electrical and pneumatic services in the Decon Cell are generally similar to those in the Main Cell. One work station in the Decon Cell is equipped with a vapor containment box for use with a pressure-spray decontamination system and another station is provided with a 30-ft-deep pit for loop handling.

Materials for shipment can be decontaminated at the spray chamber station where low-pressure spraying facilities are provided. Also, wet decontamination of in-cell equipment prior to contact maintenance in the hot repair area is performed in this cell. Since some of the equipment cannot be disassembled into small pieces, the transfer penetrations between the cells, the repair area, and the decontamination facilities are capable of accepting the largest units.

The Decon Cell has an air atmosphere and provides containment to prevent the release of particulate contamination to out-of-cell areas. The cell is maintained at a negative pressure with respect to the operating corridor, the cask tunnel, the high-bay area, and the transfer tunnel. Remotely replaceable filters and demisters are installed in the exhaust ducts within the cell. The spread of vapors from decontamination reagents is minimized by performing wet operations within closed and vented vessels such as the spray chamber.

The three 12-in.-diameter, 10-ft-deep pipes, located in the floor of the Decon Cell, are for the storage of capsules, samples, waste cans or other radioactive items which do not require forced-gas cooling. A liquid-tight cover prevents seepage into the pipes during a washdown of the Decon Cell. In addition, the storage pipes are designed for criticality-safe conditions even if flooded, although drains are provided in each pipe. Provision will be made for shielding to permit personnel entry into the Decon Cell.

Extended-reach master-slave manipulators are installed at all active stations. A five-ton crane and an overhead E-M manipulator are provided. These units are identical to those in the Main Cell and are also equipped with the tongs and hooks described previously.

Most of the Decon Cell equipment is maintained or serviced without having personnel enter the cell. Some major equipment changes or repairs, however, are carried out only by direct contact by personnel using tunnel suits.

8. Hot Repair Area

The hot repair area is located on top of the Main and Decon Cells within the high-bay area enclosure. The repair area is divided into a number of separate rooms. These include the hot repair room, suspect repair room, access room, isolation room, and hot change room. Hatches and doors are provided for the transfer of equipment or personnel between the rooms, to the high-bay area, and to the Decon Cell. A concrete block wall and a steel containment wall separate the hot repair room from the change room. The containment wall has removable panels for the insertion of glove ports, tunnel suits, and transfer devices. Windows are located in the walls of the repair rooms and access rooms.

The purpose of the hot repair area is to provide a contained enclosure in which contaminated or suspect equipment can be repaired by personnel wearing protective clothing. These repair operations include rebuilding of mechanical master-slave manipulators, repair of the Main and Decon Cell telescoping-tube and crane carriages, and maintenance or modification of examination equipment.

Experience at other facilities has shown the need for at least two types of repair areas. One area, designated as the "suspect repair room," is needed for extensive repair activities requiring extended personnel contact. Items entering this room are first thoroughly decontaminated in the Decon Cell. Space is provided for the storage of equipment components which may be reused. Workbenches and a sink connected to a suspect drain are available for the repair work, and the room is routinely cleaned to minimize the contamination level.

A second area is required to perform minor adjustments or repairs which cannot be done remotely in the Main or Decon Cells. Experience has shown that wet decontamination is both time-consuming and damaging to some machine components. Therefore, an area is needed in which rapid contact maintenance can be performed without decontamination. This area, the "hot repair room," is located for convenient access to the Decon and Main Cells without disruption to other cell operations. Equipment entering this area may have higher contamination levels than the items transferred to the suspect repair room.

The shielded penetration (Pen. 7.2008) between the Decon Cell and hot repair room is sized to pass the 7-ft-diameter by 10-ft-high transfer chamber used in the transfer tunnel. The roof hatch into the hot repair room is also sized to pass the chamber. The transfer chamber is the largest single piece of equipment to be removed from the cell complex. Large clean equipment enters the facility through the roof hatch in the access room for subsequent transfer into the Decon or Main Cells. Bag-out ports are provided in the repair room containment wall for the insertion or removal of small equipment and tools.

The containment walls located in the repair rooms consist of sheet metal walls attached to structural support members. Penetrations with flanged sealing surfaces are provided in the walls for the installation of gloved repair panels, tunnel suits, gloveboxes, transfer devices and windows.

The pressure in the repair room is maintained negative with respect to the high-bay area and the access room. The pressure within the suspect change rooms and isolation areas is also maintained negative with respect to the high-bay area, but positive with respect to the repair rooms. Air from the entire repair area is exhausted through the suspect cell exhaust system. The hot repair area walls are 8-in. hollow concrete blocks; however, provision has been made for the installation of additional shielding around the hot repair room in the future.

9. Material-handling Routes

EBR-II subassemblies and capsules, TREAT loops, and other items under 12 ft in length which are contained in top-opening casks can be transferred into the cell complex through the cask tunnel. The cask tunnel may accommodate specially designed casks which fit within the space envelope available. The tunnel height is approximately 16 ft. Gastight casks may be coupled directly to the Main Cell and items transferred without exposure to an air atmosphere. Nongastight casks are coupled to the Decon Cell and the items are transferred to the Main Cell through the intercell transfer tunnel and a large vacuum lock. EBR-II subassemblies requiring forced-gas cooling are transferred directly into the Main Cell from a gas-cooled cask by means of a grapple supplied with recirculating cell gas.

Long loops, up to about 30 ft in length, are lowered into the Main and Decon Cells from the high-bay area from bottom-opening casks. The penetrations into these cells are positioned over the deep pits. This arrangement permits any part of the loop to be positioned vertically at the desired height in front of a work station, or permits the loop to be stored temporarily. These loop casks are brought into the truck lock horizontally and are lifted vertically into the high-bay area by a 50-ton bridge crane.

Small samples and materials are transferred by pneumatic rabbit tubes to various areas. The facility has two 2-in. rabbits and one 4-in. rabbit. One 2-in. rabbit is used to transfer radiation monitoring smears from the Decon Cell to the health physics laboratory. The second 2-in. rabbit transfers materials between the metallurgical sampling and preparation box in the Main Cell to the shielded box in the metallographic laboratory. The 4-in. system transfers materials between the metallographic laboratory's shielded box and Main Cell station 15M. All three systems are capable of two-way transfers.

Small tools, fixtures, and special materials are introduced into the Main and Decon Cells directly at work stations through shielded inlet tubes. The inlet tubes are loaded from the second floor.

Large equipment enters and leaves the cell complex through a roof hatch in an access room adjacent to the hot repair room. Equipment and fixtures that are to be reused can be stored in a depressed, covered storage area at the center of the Main Cell.

10. Truck Lock

The truck lock is large enough to accommodate the various trucks and fork lifts which are used to transport shielded casks used in the day-to-day operation of the facility. Tall casks are transported in a horizontal attitude through the 14 x 16-ft rollup door and into the 16-ft-wide x 86-ft-long lock, Figs. I-5 and I-8.

The 50-ton high-bay crane works through a hatch in the truck lock ceiling. The crane either raises the cask to a vertical position and transports it up through the hatch (a 29-ft lift) or down through the floor hatch to the cask tunnel.

The truck lock floor loading design criteria are as follows:

- AASHO H-20-S16-44 Code
- 25-ton coffin and coffin carrier
- 50-ton cask and cask transporter (the transporter is designed to the AASHO Code).

11. High-bay Area

The 68 x 154-ft high-bay area (Fig. I-7) extends over the Main Cell, Decon Cell and truck lock and provides space for transporting shielded casks between the truck lock and access ports in the cell roof. The area is serviced by a bridge crane qualified to lift 40-tons within the entire high-bay area and 50-tons restricted to a certain area shown on Fig. I-2. The restriction is that the closest approach of the center of gravity of the load to the runway rails shall be 10 ft 9 in. At this distance the vertical components of the load are no greater than the vertical components of a 40-ton load immediately adjacent to the runway rails which analysis and qualification have been demonstrated to be acceptable.

A 6-in.-wide load path, for the center of gravity of loads greater than 20 ton, is designated, which locates the load center of gravity over the cell wall rather than over the roof of the cell or rooms below as a safety precaution in case of an accidental drop of the load. This is shown on Fig. I-2.

Fig. I-8. Elevation Section of Truck Lock (looking south).
ANL Neg. No. 103-A12228 Rev. 2.

The hot repair area and space for the repair of clean equipment are located in the high bay.

The high bay provides floor loading in designated areas (cask travel aisle, loop penetrations and cask storage area) for casks up to 50 tons. Other allowable floor loadings are as follows:

- Clean equipment repair area 150 lb/sq ft
- 50-ton cask travel aisle 50 tons dropped 1 in. on
3-ft diameter area

● Loop transfer penetrations	50 tons
● Cask storage on cell wall	40 tons/8 ft of cell wall distributed center to center
● Cell roof area	200 lb/sq ft
● Hot repair room	5-tons concentrated
● All other high-bay floor areas	150 lb/sq ft

The roof areas over the suspect repair room, the hot repair room, the equipment access room, the suspect change room and the isolation room all have a 100 lb/sq ft load limit.

12. Loop Pits

The Main Cell is supplied with two 33-in. nominal inside-diameter steel pits (22 ft long), extending 30 ft below the level of the removable steel floor. The Decon Cell is supplied with one such steel pit extending 30 ft below the cell floor. These three pits are directly below the loop cell roof penetrations (7.1005, 7.1006, and 7.2007) for direct access.

13. Equipment Maintenance Facilities

Equipment that requires maintenance is either repaired remotely within the Main Cell or disassembled remotely to conveniently sized units for contact maintenance within the hot repair room in the high-bay area. The repair room is an unshielded, particle-containing area equipped with tunnel suits and gloved walls. Decontamination of equipment preceding contact maintenance includes dry vacuuming in the Main Cell and air-jet cleaning in the Decon Cell, followed by wet wash-down when required. A personnel entry door is provided into the clean enclosed station within the Decon Cell. Tunnel suit entry through the enclosure wall is provided for contact maintenance of some general-purpose equipment.

B. Safety-related Ancillary Systems

General descriptions of safety-related systems supporting the operation of the HFEF/N are given below. Specific engineering details of the design of these systems may be found in the HFEF/N Basic Facility System Design Description (BFSDD).

1. Ventilation Systems

The general design philosophy of the ventilation systems is to provide within each component of the facility an air pattern that results in air flowing from clean areas toward areas with a slight possibility of contamination and from these areas toward those with greater possibility of contamination. The air supply and the exhaust systems, operating together, result in a suitable air balance.

There are three types of exhaust systems serving the facility:

- The exhaust from clean areas goes directly to the atmosphere without filtration.
- The building-laboratory exhaust system handles air from slightly suspect areas of the building and from laboratories and laboratory hoods. All air exhausted by this system passes through HEPA filters before being discharged to the atmosphere. This system has a static pressure requirement of approximately minus 1.0 in. WG at the connections to exhaust grilles and hoods.
- The cell exhaust system serves areas that have a high probability of being contaminated. All of the areas served by this exhaust system have in-cell HEPA filters to contain contamination within the areas. The exhaust air then flows through two sets of HEPA filters before it is discharged to the atmosphere. This system has a much more negative static pressure (approximately minus 5.0 in. WG) than does the building-laboratory exhaust system.

a. Clean Exhaust Systems

The air from the operating floor change room and the toilet rooms is exhausted through a common centrifugal fan. The air from the high-bay general area is removed by two roof-mounted centrifugal exhaust fans. The air supplied to Room 210 on the second floor is vented to the adjacent corridor. HEPA filtration of the high-bay area is scheduled.

The clean exhaust systems have manual dampers that will be adjusted during the air balancing to obtain the correct air flows. Automatic volume controls are not provided for these systems.

b. Building-Laboratory Exhaust System

This system exhausts suspect air from the following areas:

- Service floor: isolation corridor, tank room, and north equipment area.
- Operating floor: metallograph laboratory, remote metallograph room, photo office, low level laboratory, health physics office and laboratory, and the operating corridors.
- Second floor: Room 204, computer room, in-cell utility corridors, and the suspect exhaust equipment room.

The system has aluminum sheet-metal ductwork of conventional design. The exhaust equipment (filters, filter plenums, and fans) is located in the suspect exhaust equipment room on the second floor.

Thirty-three HEPA filters are installed between the horizontal dirty (upstream) and clean plenums. Each filter is taped to two connecting duct spool-pieces, one extending down from the dirty plenum, and the other extending up from the clean plenum. Dampers are provided in each duct spoolpiece (above and below each filter) for shutoff when filters are changed. The filter-plenum arrangement is an ANL standard design that has been used in most of its laboratory exhaust systems.

Two centrifugal belt-driven exhaust fans are provided, each of which handles 50% of the normal system capacity. During a normal power failure, one of the fans will operate on emergency power and handle 67% of the normal system load, thus assuring a continued, though reduced flow from the areas and hoods served by the system. Exhaust fan motors are sized for the larger flow handled by a single fan on emergency power. Felt-type shaft seals are used to limit fan leakage.

Normally open, opposed-blade control dampers (not airtight) are provided on the upstream side of each fan. Molded Neoprene-rubber flexible connections are installed on the suction and discharge sides of the two fans. Automatically operated, Neoprene-lined butterfly valves are provided on the discharge side of the fans. These are used for tight shutoff to prevent back flow from operating fans to nonoperating fans. The valves also prevent back flow into the suspect equipment room from the discharge manifold duct when fans are removed for maintenance.

Normally, the system capacity is maintained constant within close limits, regardless of the amount of resistance (within design limits) in the HEPA filters. Since all of the equipment served by this system is of the constant-volume type (exhaust grilles and proportional bypass hoods), the system capacity can be held constant, regardless of filter condition, by maintaining a constant negative static pressure in the dirty plenum. A static-pressure controller, which senses the plenum pressure, modulates the normally open dampers on the inlets to the two fans to keep the plenum pressure constant. The fans will run at a fixed volume with the suction dampers adding resistance when filters are clean and opening wide as the filters become dirty.

In case a fan fails during normal-power operation, operation continues with one fan and the condition is annunciated in the operations office. If the fan failure is caused by a motor failure or a motor-overload condition, the operation of the auxiliary contacts in the motor starter will cause the fan's discharge butterfly valve to close, thus preventing back flow through the nonoperating fan. If the fan failure is caused by belt breakage or

other mechanical trouble (motor continues to run), a differential flow switch will sense the decreased differential and trip an alarm.

Each of the two fans is supplied from either the normal or the emergency electrical power source. One of the two operating fans is preselected to run on emergency power should a failure of normal power occur. Should the single operating fan fail during emergency power operation, the other fan will be automatically switched on. Indicator lights in the operations office show which fans are in operation. An alarm also sounds if the dirty plenum pressure rises to a predetermined value.

In the case of loss of normal power, tests performed on the diesel generator indicate that the time required for startup and transfer of power is 11 seconds or less. During several seconds (3 to 5) of this period, the exhaust fans for the cell system and the building-laboratory system will continue to supply some flow because the fan wheels coast after power fails. In order to take full advantage of this coast-down, the automatic discharge valves, which normally close when loss of flow is detected, are set to remain open as long as there is a significant flow and to open more rapidly than they close to reestablish flow as quickly as possible.

The pressure in the Decon Cell with respect to the operating corridor, was monitored for several minutes after shutdown of the cell exhaust fan. The cell pressure did not go positive with respect to the operating corridor within the sensitivity of the manometer (about 0.01 in. WG). Under normal conditions, there should be no reversal during the transfer from normal to emergency power.

The fans in the supply and exhaust systems are sequenced to start up so that no electrical overloading occurs during the transfer to emergency power, and the building ventilation system remains balanced. This is achieved by delaying the startup of the supply fans by 10 seconds after the transfer to emergency power. Only one of the two fans to the refrigerated and the evaporative cooled air supply systems, and the building-laboratory exhaust systems, are energized on emergency power.

Corrective actions that take place in the event of exhaust fan failure are as follows:

- For the building-laboratory exhaust system, either one of the two fans will be preselected to run on emergency power. If the preselected fan fails anytime while on emergency power, the other fan is automatically started after an adjustable time delay of less than 10 seconds.
- For the cell exhaust system, the full-capacity standby fan can be started within approximately 30 seconds (manually) after fan failure is detected.

- For the supply systems, an automatic switch-over is not provided, since the loss of supply air does not unbalance the ventilation system. However, the exhaust and supply system are interlocked so that the proper supply fan is shut down automatically if an exhaust fan should fail.

c. Cell Exhaust System

This system exhausts highly suspect air or argon from the following areas:

- Isolation area 008
- Transfer tunnel
- Cask tunnel
- Decon Cell
- Main Cell
- Temporary enclosures in the high-bay area
- Hot repair room
- Suspect repair room
- Elephant trunk connection for exhaust of portable hatch enclosure
- Miscellaneous equipment

All ventilation air from the transfer tunnel and the repair rooms is exhausted into the Decon Cell. The air leaving the Decon Cell is pre-filtered through HEPA filters.

In the spray chamber, the exhaust air will frequently be quite humid as a result of the decontamination operations. The exhaust air passes through a demister and cooling coil to remove moisture, then it is mixed with air from the Decon Cell to further reduce the humidity.

The system has welded, light-gauge aluminum ductwork and filter plenums with gasketed flanged connections. The exhaust equipment consists of a filter and plenum arrangement, with sets of HEPA filters, similar to the building-laboratory exhaust system located in the sub-cell area and in the suspect exhaust equipment room.

Three fans are provided (one to be installed after startup). The planned mode of normal operation will be to run two of the three fans at all times. Failure of either fan would activate an alarm and demand action to manually start the third fan. When this occurs, operations that require "full" air flow will be carefully controlled or curtailed by administrative

means until both fans are back on line. At least one fan will run on emergency power. Flow with one fan will be at least 75% of that obtained with two fans. Until the third fan is installed, the two existing fans will be run with the same operating restrictions for failure of either of them. This system has the same type of volume-control dampers, flexible connections, butterfly valves, and controls as those described for the building-laboratory exhaust system.

A variable exhaust flow of 3000-3600 cfm is drawn from the Decon Cell to maintain the cell at a slightly negative pressure with respect to the operating corridor. The hot repair room, the suspect repair room, and the transfer tunnel are exhausted through openings into the Decon Cell. The flows from other inlets into the system are variable. The static pressure in the dirty plenum is maintained at a constant negative value between minimum and maximum flow conditions by modulating the fan inlet control dampers. Indicator lights in the operations office show which of the fans is in operation. Should the plenum static pressure rise to a predetermined value, an indicator light and an alarm bell will be energized in the operations office.

The Decon Cell, designed to run at the lowest pressure in the entire building with the exception of the Main Cell, is controlled at minus 1/2-in. pressure relative to the operating corridor, which is slightly negative relative to the outside. The pressure in the transfer tunnel and cask tunnel area is normally 0.15- to 0.25-in. negative relative to the operating corridor. The hot repair area is maintained positive (at least 0.1 in.) relative to the Decon Cell, and negative (at least 0.1 in.) relative to the high-bay area.

The office area and the high-bay area are normally slightly positive relative to the outside. All pressure differentials have been confirmed by actual measurements.

A common stack, extending approximately 10 ft above the high-bay roof serves the cell exhaust system and the building-laboratory exhaust system.

All of the HEPA filters in both the building-laboratory exhaust system and the cell exhaust system were DOP tested prior to installation. All of the out-of-cell HEPA exhaust filters will be tested in place with DOP on a routine maintenance schedule (every 6 months). The in-cell filters will be DOP-tested in place after remote replacement. Continuous monitoring of the argon circulation system will indicate a particulate leak in the system. Should a leak occur the cell circulation system will be shut down and the filters changed. Any gas discharged from the Main Cell, except in an extreme overpressurization, is directed to the cell exhaust HEPA filter system before it is released to the atmosphere. Therefore, even in the

case of a failure of the in-cell filters, normal exhaust discharge gas receives two HEPA filtrations and emergency exhaust discharge gas receives one HEPA filtration.

The installation of charcoal filters in the Decon Cell exhaust system was not considered necessary because the normal operations performed in the cell will not result in the release of fission products. Decon Cell operations will involve handling subassemblies, elements, and capsules. It is not considered credible that dropping a subassembly would breach the fuel cladding because of the structural configuration of the subassembly, which consists of a tight bundle of clad fuel elements confined inside one or more tightly fitting envelopes of stainless steel hexagonal tubing. Furthermore, the subassemblies are lifted or carried no more than three feet above floor level.

However, if a single capsule were to be dropped it is conceivable that the cladding could be breached. (This is a worse case than dropping a single element because of the larger size and greater fission product inventory of capsules.)

The maximum amount of iodine which could be present in a capsule would be 140 curies. Calculations show that with the present protective system the thyroid dose at Mud Lake, the nearest populated center, would be far below the 10 CFR 100 allowable dose of 300 rem even if all of the iodine were to escape from the capsule and from the cell (see Section IV.C for additional pertinent information).

2. Argon Atmosphere in Main Cell

The argon atmosphere system is designed to provide a controlled environment for the operations performed in the Main Cell. Pressure and impurities (such as oxygen and moisture) are regulated to specific levels.

Figure I-9 shows the flow diagram for the argon system. This system comprises seven subsystems: (a) cell pressure and temperature control; (b) primary-loop cell cooling; (c) purification loop; (d) exhaust; (e) over-pressure relief; (f) gas supply; and (g) reactor subassembly pit cooling.

The cell temperature- and pressure-control subsystem maintains the cell atmosphere within the design temperature and pressure limits. The primary-loop cell cooling subsystem dissipates the heat liberated within the cell by lights, equipment, reactor subassemblies, and the circulation fan. The purification-loop subsystem is a branch of the primary loop and provides for the removal of oxygen and water vapor resulting from air in-leakage. Equipment for a duplicate standby purification system has been installed. The exhaust subsystem removes gas from the cell,

Fig. I-9. Flow Diagram of the Argon System. ANL Neg. No. 103-A12230.

as directed by a differential pressure controller, to keep the cell pressure negative with respect to the building atmosphere. The over-pressure relief subsystem removes gas from the cell if the internal pressure should rise to 3 in. WG above the building atmosphere. The gas supply subsystem feeds gas to the cell, as directed by static differential-pressure controllers, to keep the cell from becoming too negative with respect to the building atmosphere. The reactor subassembly pit cooling subsystem cools the subassemblies with recirculated cell gas.

The normal operating pressure range, emergency pressure range, and other characteristics of the cell are given below:

Design Criteria

- Site normal barometric pressure: 12.22 psia (5000 feet altitude)
- Cell gas: argon (Main Cell)
- Design maximum in-cell leakage: 0.01 cfm
- In-cell heat loads:

experimental equipment	20.0 kW
radioactive decay	13.0
cell lighting	50.0
in-cell cranes, transport door drives, etc.	1.0
storage-pit blowers and grapple blower	21.0
future equipment	16.0
Total	<u>121.0 kW</u>
- Cell cooling system capacity: designed for sufficient capacity so that even if a constant cell-to-atmosphere pressure differential is maintained, no cell gas will be exhausted during a barometric pressure drop of 0.7 in. Hg in 24 hours.

Operating Ranges

- Normal cell pressure range: 0.75 to 4 in. WG below atmospheric pressure
- Cell water vapor content: 40-50 ppm (nominal) by volume
- Cell O₂ content: 25-50 ppm (nominal) by volume
- Cell temperature operating range: 70 to 100°F

Setpoints for Initiation of Auxiliary Control

- Cell pressure: +3 in. to -8 in. WG relative to atmospheric pressure
- O₂ content: 15 ppm by volume (purification loop effluent)
- Water vapor content: 40 ppm by volume

The gas purity requirements were established on the basis of the fuel materials planned for examination, the experimental procedures, and the sample preparations envisioned. With argon as the cell atmosphere, the nitrogen levels will be controlled by gas makeup and exhaust and, under these conditions, the equilibrium nitrogen levels will probably be between 5 and 10%.

The "weak link" in the Main Cell structure relative to overpressurization is window 20M. This window is calculated to withstand a pressure of approximately 1 psi with a safety factor of 7. Calculations show that the remainder of the Main Cell windows should withstand a pressure of approximately 3.8 psi with the same safety factor of 7 without cracking.

3. Transfer Penetrations

The transfer system for this facility is more complex than those encountered in most hot-cell facilities because of the variety of irradiation programs being serviced, the argon atmosphere in the Main Cell, and the general requirement for preventing the release of particulate contamination to personnel-occupied areas.

All irradiated components will be shipped to HFEF/N in shielded casks. The components will vary in size from 0.187-in.-diameter, 18-in.-long EBR-II fuel elements to a 30-ft-long packaged loop from ETR containing ruptured fuel elements submerged in sodium. A wide variety of shielded casks must be accommodated, including top-opening, bottom-opening, gastight, nongastight, and possibly water-filled casks.

Operating experience at other facilities was considered in establishing this system of transfer penetrations. For example, an equipment decontamination and repair facility convenient to the air and argon cells proved necessary in the EBR-II Fuel Cycle Facility to improve the operating efficiency. Such an area is provided in HFEF/N and, hence, a transfer path to the area is required. Redundancy of critical flow paths, quick access for tools and materials directly into each cell, and a pneumatic tube for rapid and contained transfer of samples between cells and laboratories are also provided on the basis of experience at other facilities.

The design basis for selecting the number, size, and location of the cell transfer penetrations in HFEF/N was determined by the material flow diagram, Fig. I-10. Each penetration in this generalized flow diagram has

Fig. I-10. Flow Diagram of the Material-transfer System. ANL Neg. No. 103-12229 Rev. 1.

a unique identification number and is shown in its relative cell position; i.e., in the cell roof, walls, or floor. General design requirements established for the penetration include the following:

Main Cell Design Criteria

- Penetrations must be gastight at all times with means for verifying the leaktightness of individual seals.
- The interface seal between gastight shipping casks and the penetration must be gastight and have a means for verifying the leaktightness of the seal before the primary cell sealing closure is opened.
- A clean argon gas supply line and a suspect exhaust line are to be provided for purging the interface volume between the shipping cask valve and the primary cell sealing closure.
- All shipping casks that are to mate with the Main Cell penetrations must be gastight.
- Penetrations to routinely occupied out-of-cell areas must be fully shielded when closed; that is, equivalent in shielding to the wall, roof, or floor in which they are located.
- Carbon steel is acceptable for use on all penetration liners, but must be painted or treated for corrosion resistance.
- Concrete surfaces are not to be exposed to the Main Cell atmosphere.
- Mechanisms, shielding plugs, and seals used in all penetrations are to be replaceable without affecting the cell atmosphere, releasing radioactive contaminants, or exposing personnel to radiation levels in excess of the specified levels.

Decon Cell Design Criteria

- The release of radioactive particulates to out-of-cell areas is to be controlled by ventilation flow.
- The interface seal between shipping casks and the penetration must be designed to prevent the release of particulates during transfers.
- Penetrations to routinely occupied out-of-cell areas must be fully shielded when closed; that is, equivalent in shielding to the wall, roof, or floor in which they are located.

- Painted carbon steel is acceptable for use on all penetration liners.
- Mechanisms and seals used on all penetrations must be replaceable without releasing radioactive contaminants to out-of-cell areas or exposing personnel to radiation levels in excess of specified levels.

Not all of the penetrations were activated for the startup of HFEF/N. Descriptions of the significant design features of those which are activated are given below.

a. Cask Tunnel (Penetrations 7.2010, 7.2002, 7.1012)

The cask tunnel is about 70 ft long x 12 ft wide x 13 ft high with a 4-ft-wide x 4-ft-deep trench extending the length of the tunnel, Fig. I-11. An 8 x 8-ft hatch in the roof of the tunnel allows casks to be lowered from the truck lock into the tunnel. Three shielded ports are located in the roof of the tunnel for entry to the clean area (of the Decon Cell), the Decon Cell, and the Main Cell.

A self-propelled cart capable of carrying a 20-ton cask operates in the tunnel. It runs on rails embedded in the tunnel floor and transports top-opening casks between the truck lock hatch and the desired cell penetration. A control console is located on the cart. A special adapter containing a lifting mechanism is used on the cart to accommodate the variety of casks that must be handled.

b. Transfer Tunnel (Penetrations 7.1001, 7.2001)

The shielded transfer tunnel is used for the movement of large equipment and irradiated components between the Main and Decon Cells. Equipment in the tunnel, shown in Fig. I-12, includes a 10-ton capacity cart which is chain driven and runs on rails embedded in the floor and a 6-ft-diam x 8-ft-high vacuum chamber which is carried on the cart. One 10-ton hydraulic lift is located in the floor of the tunnel directly below the Main Cell penetration and another beneath the Decon Cell penetration.

When the cart is in position beneath either of the penetrations, the lift raises the vacuum container. The container forms the lower part of a 6-ft-diam x 12-ft-high vacuum lock when raised against the Main Cell penetration. Before the Main Cell lock cover is opened, the lock is evacuated and backfilled with argon.

Since the transfer tunnel will become contaminated, some provisions for contact maintenance have been made. The cart drive motor and hydraulic lift pumps are located outside the tunnel and the vacuum chamber

can be raised into the Decon Cell for gasket replacement. A special insert has also been provided for the vacuum container to accommodate long slender components, such as TREAT loops and EBR-II subassemblies, and to reduce the volume of the chamber when transferring small pieces of equipment.

Fig. I-11. Cask Tunnel and Cask Cart. ANL Neg. No. 104-232 Rev. 2.

Fig. I-12. Transfer Tunnel System. ANL Neg.
No. 104-233 Rev. 1.

c. Small Equipment In-Cell
Transfer Lock (Penetration 7.1002)

This vacuum lock interconnects the Main Cell and the Decon Cell as shown in Fig. I-13. The lock will accommodate an item 12 in. wide x 18 in. high x 5 ft long, weighing up to 500 lb. The doors on the lock have an air-motor-operated clamp for sealing and are rotated open and closed by master-slave manipulators. Interlocks are provided to prevent both doors from being unclamped simultaneously.

A tray mounted on a drawer-slide within the lock extends into either cell so the item being transferred can be placed on the tray with either master-slave manipulators or the overhead electromechanical manipulator.

d. Decon Cell to Repair Area Hatch (Penetration 7.2008)

A large penetration (7.5 x 7.5 ft) is located in the ceiling of the Decon Cell, as shown in Fig. I-13. It is used for the transfer of large equipment by the 5-ton crane in the repair area. The shielding cover over the hatch is 9 ft x 9 ft x 12 in. high and is made of steel slabs. Twelve 12-in. diam, commercially available air bearings support the 20-ton cover, which is opened and closed by a small chain-driven motor unit.

e. Shielded Personnel Access Doors (Penetrations 7.2004, 7.3001)

Plug-type shield doors are located in the clean area (Decon Cell) and the transfer tunnel and permit infrequent personnel entry. These doors are supported on commercially available air bearing pads and are manually opened and closed.

f. Gravity Tube Transfer System (Penetrations 7.1007, 7.1008, 7.2009)

Three 6-in.-diam tubes are embedded in the cell walls for transfer of small tools and equipment directly into the cells. The tubes originate on the second floor and terminate in the cell (see Fig. I-13). Figure I-14 shows the main features of the system. Two tubes are directed to the Main Cell and one (not shown) into the Decon Cell clean area. The items

Fig. I-13. Transfer Systems. ANL Neg. No. 104-234.

Fig. I-14. Small Equipment Transfer Lock.
ANL Neg. No. 104-235.

to be transferred into the cell are placed in a container (maximum size is 4 in. diam x 16 in. long) which is inserted into the loading chamber and moved by gravity into the cells. As shown in Fig. I-14, the tubes are inclined and curved in such a way that supplemental shielding is not required.

g. Pneumatic Transfer Systems.

7.1017: The pneumatic transfer tube penetration consists of a 2-in.-diam tube interconnecting the station containment box in the Main Cell at work station 2M and the loading cell located in the metallograph room. The tube will be used for the rapid transfer of 1½-in.-diam, 6-in.-long cans or "rabbits" containing 1-in.-diam, 1-in.-long metallographic specimens prepared in the Main Cell. A loading station just large enough to take the rabbit is attached to the pneumatic tube at each end.

The pneumatic tube extends down through the Main Cell and runs beneath the basement floor to a point under the metallograph room. Here the tube is brought up through the floor vertically into the loading cell on the floor above. The vertical tube section may be shielded if required.

7.1016: This penetration is a 4-in. waste transfer system between the metallograph loading box in the metallography laboratory and the Main Cell. Wastes from the loading box will be transported to the Main Cell and ultimately out through the clean area of the Decon Cell through the solid waste handling system.

7.1010: This penetration provides the argon supply and exhaust for above 4-in. waste transfer system.

7.2005: This is a 2-in. two-way transfer system between the air cell of HFEF/South and the Decon Cell. HEPA filters are installed to assure the discharge from the transfer tube into the suspect exhaust system is free of contamination.

7.2003: This pneumatic transfer tube connects the Decon Cell with the health physics laboratory for the transfer of 2 x 2 in. radiation contamination smears for examination.

h. Penetrations for Future Use

The following penetrations exist but will not be activated until needed. All are blanked off and have gastight seals and shield plugs where necessary.

7.1004: This penetration is a blanked port 12 inches in diameter located in the Main Cell ceiling which could be used as a transfer port for capsules and elements into and out of the Main Cell.

7.1005: This is a $25\frac{1}{4}$ -in.-diameter opening in the Main Cell ceiling intended for use for the vertical transfer of loops or other items into the Main Cell from bottom-opening casks. The LMFBR Sodium Loop Safety Facility has been used as the reference to establish operational parameters.

7.1006: This penetration is identical to 7.1005. It will in the future provide the capability of working on two reactor loops simultaneously in the Main Cell.

7.1011: This is a blanked 5-in. port in the floor of the Main Cell.

7.1013: This penetration is a 6-in.-diameter sealed opening located in the Main Cell floor interconnecting with the cask tunnel. The penetration will be used for the foil transport system of a neutron radiography installation to be provided later.

7.1014 and 7.1015: These are two 12-in.-diameter blanked ports in the floor of the Main Cell which could be used in the future for transfer of capsules and samples for neutron radiography.

7.2006: This is a blanked 18-in.-diameter port in the west wall of the Decon Cell.

7.2007: This penetration is identical to 7.1005 and is located in the ceiling of the Decon Cell. It will provide future capability for decontaminating a loop that has been reassembled in the Main Cell before it is shipped from HFEF/N.

7.2011: This is a blanked 5-in. port in the floor of the Decon Cell.

4. Normal Power

The normal supply of electric power is delivered at 480 volts, 3 phases, 60 Hz by four underground cable feeders from the 13.8-0.48 kV substation, located at the west end of Building E-765 (HFEF/S). This substation also feeds Building E-765 and consists of the following major components:

- Two 13.8-kV fused load-interrupter switches;
- Two 1500-kVA, dry-type, self-ventilated, 13.8 to 0.48-kV transformers;
- One 480-V metal-clad, draw-out type circuit breaker section, including two main breakers, one tie breaker, two 480-V bus sections, branch breakers, meters, and instruments.

Each transformer feeds one of the 480-V bus sections and, under normal operating conditions, the tie circuit breaker between the two bus sections is open. In case the power supply to one of the 480-V bus sections is lost, the tie circuit breaker is closed manually and power is supplied to both sections of the bus from one transformer. To prevent the main 480-V circuit from tripping on a branch feeder fault, the two main circuit breakers are equipped with selective trip devices coordinated with the branch circuit breakers. All 480-V substation circuit breakers are equipped with adjustable ground-fault trip devices. These devices prevent damage to electrical equipment from ground faults of magnitudes lower than the trip settings of the circuit breaker phase-overcurrent elements.

One HFEF/N 480-volt cable feeder feeds a 600-ampere plug-in type bus duct that supplies power to most of the in-cell equipment. The other three feeders feed seven motor control centers. The motor control centers supply power and provide control for a majority of the electric motors and other larger loads. Power for in-cell equipment, building lights, and miscellaneous smaller devices is transformed from 480 to 120/208 V.

5. Emergency Power

An emergency power generator is installed on the service floor of the HFEF/N building. In case of failure of the normal power supply to the bus that feeds essential loads, the 200-kW, 480-V, 3-phase, 60-Hz, diesel-powered generator will automatically start and supply power to the following essential loads:

- (1) one of the evaporative cooling supply fans
- (2) one of the air conditioning supply fans
- (3) one of the building-laboratory exhaust fans
- (4) subassembly-pit cooling blowers
- (5) selected radiation monitoring
- (6) fire alarms and Halon system
- (7) intrabuilding communication network
- (8) two argon purification compressors
- (9) HFEF/S suspect exhaust stack fan No. 1
- (10) two cell exhaust fans
- (11) evacuation and equipment alarms
- (12) self-contained cooling grapple
- (13) control instrumentation

- (14) cell incandescent lighting fixtures and strategically located building lighting fixtures
- (15) one instrument air compressor
- (16) selected in-cell-handling equipment (3 E/M, 3 cranes, repair hoist)
- (17) elevator
- (18) 50-ton high-bay bridge crane
- (19) 5-ton hot repair area crane
- (20) 2-ton high-bay area hoist
- (21) cooling tower pan heaters
- (22) cask tunnel transfer cart
- (23) transfer tunnel hydraulic lifts
- (24) transfer tunnel cart drive
- (25) two duplex condensate return pumps
- (26) four clear water sump pumps
- (27) Decon Cell sump pump.

When the diesel generator approaches its rated voltage and frequency, the loads listed above are automatically transferred from the normal power source by a transfer switch. Normally, essential loads will be transferred to the diesel-generator power supply within 11 seconds after the loss of normal power. Manual methods are used to transfer these loads back to the normal power supply and to stop the diesel engine. Provisions are made for periodically testing the emergency generator at full load without interrupting the power supply to the emergency loads. The diesel engine is started by means of an electric storage battery, which is equipped with a trickle-charging system.

None of the components of the Main Cell cooling system (i.e., pumps, fans, compressors) are connected to emergency power. The Main Cell pressure-temperature control system is connected to the emergency power source so that indication and annunciation of cell pressure remain after loss of normal power.

The Decon Cell is cooled by a flow of ventilation air from cooler adjacent areas drawn through the Decon Cell by cell exhaust system fans, which are on emergency power.

The diesel is inspected once each week. After a prestart check list is completed of all parameters (battery voltage and water and oil levels), the engine is started and allowed to reach operating temperature. Operating parameters are recorded and a postoperating check list is completed; the check sheet is reviewed and signed by the Plant Services foreman.

Once each quarter the run test includes picking up the building emergency load for a 30-minute period. Check lists are completed and reviewed similar to the weekly ones. A detailed maintenance schedule is followed for the diesel generator and support systems with appropriate items on a quarterly, semiannual, and annual basis.

To improve the reliability of the power supply to several highly essential loads, a backup emergency electrical power (BEEP) system is provided. The system consists of a 60-kW, 480-V, 3-phase, 60-Hz diesel-engine driven generator (derated to 55-kW due to high altitude) with associated switching and control equipment. Upon failure of normal power supply, the 200-kW diesel engine is automatically started and emergency loads are switched to this diesel. If the 200-kW generator or transfer switch fails, the BEEP system is started and the following loads are automatically switched to the BEEP: one cell exhaust fan, the S/A pit cooling blowers, the instrument air compressor, critical radiation instrumentation, and the power supplies for the public address system. If both diesel generators are not available or do not start, the building will be evacuated and be considered as a suspect airborne contamination area per the HFEF Emergency Plan.

6. Radiation Monitoring

The radiation monitoring system supplies exposure-rate data for use in minimizing personal exposures, minimizing the spread of radioactive contamination, and actuating personnel evacuation alarms if dangerous conditions arise. The system measures exposure-rate levels in building areas and from individual items of equipment, radioactive gases, particulates dispersed in the air, and contamination on personnel.

The system includes stationary continuous monitoring instruments, survey instruments, stationary personnel monitors, and low-level-radiation-measuring instruments. Continuously operating gamma detectors and air monitors are located in various areas of the facility. A stack monitor is located downstream of the building exhaust HEPA filters to record background exposure-rate data and to actuate an alarm if the area or air exposure rate exceeds a specified level. The air monitors detect both alpha and beta-gamma radiation. In case of a power failure, all radiation monitoring instruments which are not self-powered will receive power from the emergency power system.

The stack monitor system will include adjustable high radioactivity alarms. Proposed alarms are at the following concentrations, assuming design criteria are met:

Gross alpha	$1 \times 10^{-9} \mu\text{Ci/cc}$	Gross gas	$3 \times 10^{-6} \mu\text{Ci/cc}$
Gross beta	$3 \times 10^{-9} \mu\text{Ci/cc}$	^{133}Xe	$3 \times 10^{-5} \mu\text{Ci/cc}$
^{137}Cs	$5 \times 10^{-8} \mu\text{Ci/cc}$	^{85}Kr	$1 \times 10^{-3} \mu\text{Ci/cc}$
^{131}I	$1 \times 10^{-8} \mu\text{Ci/cc}$		

The set points will be established in accord with AECM 0524 and 10 CFR 50.

Portable survey instruments and personnel monitors are used to measure exposure rates due to neutron, alpha, and beta-gamma activity from direct radiation, from particulate contamination on personnel, equipment, or surfaces, and from contamination smears taken remotely in the decontamination cell.

Alpha and beta-gamma personnel monitors are located between various areas in the facility--and between the facility and the immediate environment--to detect personnel contamination before it is spread into other areas.

Low-level alpha and beta-gamma detectors, counters, and sample preparation equipment are located in the health physics laboratory. This equipment is used mainly for detecting contamination.

The remote alarms for the area and air monitors are located in the Radiation Safety office as well as the operations office. The alarms are annunciated in the EBR reactor building during off-shift. Also, Radiation Safety personnel will be aware that an alarm condition occurred, even if the condition either corrected itself or was acknowledged.

Criticality incident detectors and alarm systems are provided to warn of the necessity for immediate evacuation of the building.

7. Waste-handling Systems

a. Suspect Liquid Wastes

The suspect liquid waste system (Figs. I-15 and 16), consisting of two 1500-gallon retention tanks and suitable pumps, is located in the northwest corner of the HFEF service floor. The area containing the pumps and tanks is depressed 6 in. below normal floor level in order to contain any spill or tank overflow that might occur. Suspect liquid wastes flow to either one of the two 1500-gallon retention tanks. Tank 301 receives the wastes from various laboratory drains in the building. It is constructed of steel plate with a 6-mil coating of a phenolic compound (Plasite 3055) for protection against corrosion. The tank is rated at 15 psig and tested to 22.5 psig. Tank 300 receives effluent from the Decon Cell, and transfer tunnel drain systems, the hot repair area and the suspect repair area. It is constructed of stainless steel and is also designed for 15 psig and tested to 22.5 psig.

Both tanks are provided with high level detectors which actuate audible and visual alarms on the HFEF alarm panel. The tanks are also

Fig. I-15. Suspect Liquid Waste System. ANL Neg. No. 103-A12232.

TO SUSPECT LIQUID
WASTE SYSTEM
(SEE FIG. I-15)

Fig. I-16. Decon Cell Drain System

commonly vented to the laboratory exhaust system. Transfer pumps and a valve manifold permit tank circulation and transfer to the site industrial waste system, the Laboratory and Office Building (Building 752) evaporator system, or to a truck loading system outside HFEF/N. A truck overflow system is routed to the depressed floor area and, via a floor drain, to the suspect waste area sump. A pump directs fluids from the sump into tank 300. The circulation system for the Decon Drain tank includes filters.

A constant air monitor is installed in this area.

The normal transfer of wastes from tank 301 found to be inactive will be into the industrial waste line in the HFEF/S basement, and thence to an open ditch that drains into the industrial waste pond. Wastes from the Decon Cell in tank 300 will normally be routed through the HFEF/S basement to the evaporator retention tanks in the Laboratory and Office Building. In the event that suspect wastes cannot be pumped to the Laboratory and Office Building evaporator system, the transfer pump can be directed to the truck loading station where a truck may be connected by hose to the discharge.

b. Solid Wastes

The solid waste transfer system provides a means of packaging and transferring contaminated solid wastes resulting from the various activities performed in the Main and Decon Cells. Packaging and transfer are accomplished without contamination of the external surfaces of the containers.

The system consists of bag-out provisions between each of the three floor plugs (two in the Decon Cell, one in the Main Cell) and the cask in the cask tunnel.

Waste cans will be seal-welded closed prior to their removal from the facility.

8. Service and Fire-protection Water

Two separate underground water lines connect to an existing 10-in. underground water main located approximately 30 ft south of HFEF/N. A 4-in. branch line from the 10-in. main provides the potable water to the building. The fire-protection water is delivered to HFEF/N through a 6-in. branch line. Both branch lines are equipped with post indicator valves, and the lines enter the service floor of the building. A new hydrant, installed north of the building, is fed from the building fire-protection water and is on a 4-in. dead-end line. This hydrant is not equipped with a pumper connection.

The EBR-II supply of fire-protection water is sufficient to handle a simultaneous occurrence of fires in the EBR-II complex and HFEF/N. Two

areas of the HFEF/N Building, the generator room and the truck lock, are equipped with sprinklers. A connection is available for extension of the sprinkler system to other areas if necessary.

9. Fire Alarms

Manual fire-alarm stations, located near each exit and each stairway, are connected through a conduit system to the fire-alarm terminal area on the operating floor. These, as well as the automatic sprinklers, smoke detectors, and heat detectors, are connected into a central monitoring and annunciator panel located in the operations office. In case of fire, the alarm bells, audible throughout the building, will be activated and the alarm signal transmitted to the local and the INEL Central Facilities fire stations.

10. Building Equipment Alarms

To provide audible and visual alarms when building equipment malfunctions or when essential operations are interrupted, alarm panels are installed in the operations office. These panels consist of illuminated, inscribed-window-type annunciators. When a monitor connected to one of these annunciators indicates a malfunction, the light behind the inscribed window flashes on and off and horns sound in the office and parts of the building. An acknowledge button (in the office) permits silencing the horns after which the alarm light glows steadily. When the alarm condition has been corrected, the light goes out and the alarm unit is automatically reset.

Abnormal conditions of the following systems will activate the building equipment alarms:

- radiation monitoring
- Main Cell cooling
- Main Cell atmospheric conditions
- Main Cell purification loop
- subassembly cooling
- argon supply
- compressed air
- atmospheric pressure in radioactive air cells
- exhaust systems
- air supply
- laboratory water
- suspect fluid retention and drainage
- transfer system hydraulic fluid pressure.

A list of the parameters and set points for system conditions annunciated on the operations office panel board is given in Appendix A. Examination of the annunciator board is necessary to determine the status of the emergency power system for there are no direct indicators or alarms for the emergency power system. A loss of power actuates all of the alarms except the gamma alarm, which is on battery backup. The air particulate monitors have a time delay which results in a delayed alarm following loss of normal power (preventing alarm and evacuation before the emergency diesel(s) pick up the load).

The operations office is not manned at all times, but personnel assignments assure that appropriate personnel trained to respond to alarms are on duty in the building during all normal working hours.

11. Grounding and Lightning Protection

The HFEF/N building and equipment are grounded by a bare 4/0 copper cable buried around the outside of the building and connected to the existing site grounding grid. At 50-ft intervals around the building, ground rods are installed and connected to the cable. Electrical equipment enclosures, metal building columns, and transformer neutrals are connected to this system. Except for the lighting fixtures, all 480-V, 208-V and 120-V electrical equipment enclosures and receptacle ground terminals are grounded by insulated wire run in the same conduit with the power-supply wires.

Lightning protection for the HFEF/N building is provided by standard air terminals and down-conductors connected to the 4/0 building ground cable loop.

SECTION II
OPERATIONS

II. OPERATIONS

A. Functions of the HFEF/N

1. Nondestructive Examination of Capsules and Elements

Fuels and structural materials of interest in the LMFBF materials-development irradiation programs are normally irradiated in the form of test capsules and elements. An array of capsules or elements usually comprises the irradiation-test vehicle known as the "experimental subassembly." In the case of loop irradiations (for example, those parts of the Sodium Loop Safety Facility, SLSF), a similar array of capsules and elements is referred to as the "test train." LMFBF experimental irradiation capsules and elements are usually cylindrical, with diameters ranging from 0.175 to 0.805 in., lengths ranging from about 1.5 to 8 ft, with thin spacer wires helically wound at either a 6- or 12-in. pitch on the outsides and fastened to the ends.

A "fuel element" consists of nuclear fuel material sealed in stainless steel tubing termed the element "cladding tube." The ends of the tubes are closed with plugs welded to achieve gastight seals. Fission heat generated within a fuel element is transferred to the surface by either an inert gas (usually helium) or sodium metal within the tube. A "structural materials element" is similar to a fuel element except that no fuel is involved. In this case, the element consists of a similar sealed stainless steel tube with or without structural materials enclosed and containing either an inert gas or sodium metal as the heat-transfer medium.

A "fuel capsule" consists of a fuel element enclosed in a second stainless steel tube with sodium or inert gas between the two tube walls. Capsules are normally used for higher-risk experimental irradiations tests where double containment is advisable.

The main purpose of nondestructive examinations conducted in the HFEF/N on experimental irradiation subassemblies and loop test trains with their associated capsules and elements is to provide experimenters with the data they need in order to evaluate the performance of their test subjects at various periods in the planned irradiation lifetimes. Normally in the cases of capsules and elements, the nondestructive tests must not preclude their eventual return to the irradiation facility for additional irradiation. For subassembly hardware or the components which comprise the hardware portion of the loop irradiations test train, returnability of these components is not always required.

The following are summary descriptions of the planned nondestructive tests to be run in HFEF/N in the near future. Tests discussed are divided into those normally conducted on subassembly and test train hardware and those carried out on capsules and elements.

a. Subassembly and Test Train Hardware Tests and Examinations

(1) Straightness Tests. Upon receipt of the irradiated subassembly or separation of the loop test train from the loop assembly, total indicated runout (TIR) measurements are made at a number of axial points on the hexagonal tubing of these components. When compared with similarly obtained preirradiation measurements, postirradiation TIR measurements provide data concerning the axial bowing experienced by the subassembly. These tests are run with the subassembly straightness and tensile testing machine. One such unit is located in the HFEF/S air cell now and another is scheduled to be installed in the HFEF/N Main Cell.

(2) Hexagonal Tubing Dimensional Surveys. Flat-to-opposite-flat measurements are made at various axial positions on the subassembly or loop test train hexagonal tubing. Occasionally, corner-to-opposite-corner measurements are also made. These postirradiation dimensional surveys of the hexagonal tubing are compared with preirradiation measurements to determine whether changes such as tubing distortion, material straining or swelling, etc., have resulted from irradiation service. These dimensional surveys are made with the hexagonal tube measuring gauge.

(3) Visual and Photographic Inspection. Visual and photographic inspection of the overall subassemblies and loop test trains are made through the hot cell window. In addition, more detailed inspections with the hot cell wall periscope are carried out. These inspections are directed toward the identification of any abnormalities present on the overall subassemblies or test train hexagonal tubing.

b. Capsule and Element Tests and Examinations

After the subassemblies or the loop test trains are dismantled (with the vertical assembler-dismantler (VAD) in the HFEF/N Main Cell, or in the HFEF/S air cell, or the milling machine in the HFEF/N Main Cell), the individual capsules or elements are subjected to the following planned nondestructive tests:

(1) Visual and Photographic Inspection. With the hot cell periscopes (and possibly the hot cell stereomicroscope when available) capsules and elements are inspected visually and photographically for abnormalities which may have arisen as a result of irradiation exposure or remote handling operations. The periscope inspection is supplemented by visual and photographic inspections through the hot cell window.

(2) Weight Determination. Capsules and elements are weighed on the remote balance in the HFEF/N Main Cell. Postirradiation weights are compared with preirradiation values in order to determine whether weight increases or losses occurred which might indicate abnormal conditions

in the capsules or elements. These abnormalities could include fuel cladding losses, fission gas losses, take-up or loss of bonding or reactor sodium, etc.

(3) Balance-point Determination. Fuel elements, and occasionally structural materials capsules or elements, are checked with the balance-point measuring apparatus in the HFEF/N Main Cell. In this test, the axial position along the length of the capsule or element which is the fulcrum point about which the capsule or element can be balanced while in the horizontal position is determined. This postirradiation balance point location, when compared with preirradiation values, can be used to determine whether a change in the balance point location has resulted from reactor service. Such a change can often be attributed to relocation of the fuel material or other components in the capsules or elements, take-up or loss of bonding or reactor sodium, etc.

(4) Precision Diameter Measurements. Precision measurements of the diameters of capsules and elements are made with the vertical contact-type profilometer located in the HFEF/N Main Cell. An optical-type profilometer is planned for installation in the Main Cell later. The profilometer provides a continuous indication and recording of diameters over the entire length of the capsule or element. For capsules and elements which have spacer wires, this continuous diameter profile takes the shape of a helix since the measuring probes of the profilometer must be maintained clear of the spacer wires. Comparison of postirradiation diameter data with preirradiation data gives information pertaining to fuel swelling, cladding straining, cladding creep, and cladding swelling for the test capsules and elements, which is extremely important to experimenters for evaluation of the irradiation performance of fuels and materials.

(5) Bow and Length Measurements. Axial bowing measurements and overall length measurements are made on the capsules and elements. Bowing measurements provide information concerning thermal and neutron flux gradients, clad swelling gradients, etc., experienced by the test specimens during irradiation. These measurements also supply information often necessary for evaluation when reuse of capsules and elements in remotely refabricated subassemblies is required.

Postirradiation overall length measurements of capsules and elements, when compared to preirradiation measurements, provide data concerning straining, creep, and swelling of the cladding.

(6) Neutron Radiography. Fueled capsules and elements, and structural materials capsules and elements when appropriate, are neutron radiographed. Holders which accommodate various numbers of capsules and elements, depending upon the diameters and lengths, are loaded in the HFEF/N Main Cell and transferred in special shielding casks to the Transient Reactor Test Facility (TREAT) where the radiography is actually conducted. The test specimens in the holders are then returned to the HFEF/N Main Cell.

Postirradiation neutron radiographs provide data concerning internal configurations of the fuel, test specimens, cladding, etc., which cannot be observed directly. Indications of failure of the cladding of fuel elements enclosed in capsules is an example of the type of information which neutron radiographs can provide. In addition, postirradiation neutron radiographs of capsules and elements are compared with preirradiation X-radiographs in order to provide information regarding changes in internal configurations which have resulted from irradiation service.

(7) Gamma Scanning. The capability for gamma scanning now exists in the HFEF/S air cell. A gamma scanner will also be installed in the HFEF/N Main Cell. When the scanning of capsules and elements is carried out in the HFEF/N, the data collection portion of the precision gamma scanner (PGS) and the computer control network for the system will be located in the data collection laboratory (Room 201) while the in-cell positioning stage, collimator and detector will be located at the Main Cell. The gamma scanning to be conducted will include precision axial, diametral and radial scans, gross scans, and scans necessary for leak detection investigations on fueled elements and capsules.

Gamma scanning provides data concerning fission product migration in fuel elements, profiles of the power and flux experienced by the capsules and elements during irradiation, relative burnup and exposure data, etc., which are essential for experiment evaluations pertaining to irradiation performance.

These listed examinations and tests constitute the currently planned normal examinations for capsules and elements in the HFEF/N Main Cell. Upon completion of the examinations, the capsules and elements, if they are to be reassembled as new subassemblies for additional irradiation in EBR-II, can be transferred to the HFEF/N Decon Cell for decontamination and then to the HFEF/S air cell for reassembly into new EBR-II subassemblies using the VAD. Straightness and dimensional measurements and visual examinations (similar to those discussed earlier) will be made on the reconstituted subassemblies while they are in the HFEF/S air cell prior to transfer to the reactor. If capsules or elements are to be returned to the experimenters' laboratories, transfer from the Decon Cell to appropriate shipping casks will be made.

2. Destructive Examination of Capsules, Elements, and Other Components

The major function of HFEF/N is to perform postirradiation, non-destructive examinations and tests on irradiated fuel and structural materials capsules and elements (as described in Section II.A.1) if these experiments are intended for return to the reactor or irradiation facility for additional irradiation. However, if such additional irradiation of the capsules or elements is not required, these experiments are often subjected

to destructive examinations and tests. Also, irradiated components other than capsules and elements will be destructively examined. Examples of such components are EBR-II subassembly hardware, control rod and safety rod thimbles, in-core hardware, loop hardware, etc.

The destructive examination equipment and procedures are still in the concept stage and cannot be described in the same detail as the nondestructive tests. Further, it is expected that experience will show that destructive examinations not now foreseen will be desirable. Therefore, there are given below summary descriptions of only those planned destructive examination and testing capabilities which will be available in the HFEF/N in the near future.

a. Capsule and Element Plenum Gas Measuring

The cladding of fuel elements will be punctured in the plenum-gas region (and possibly other regions) in order to collect the fission-product gases. These collected gases will be subsequently sampled and analyzed by radiochemical techniques in order to determine gas composition, volume, and pressures present in the fuel elements. This information is important in order to assess the performance of the fuel elements as pertains to fission-product gas release from, and retention in, the fuel, stressing of the element cladding as a result of pressure buildup, etc.

Capsules which enclose fuel elements will also be punctured in the plenum-gas region and samples of this gas collected for radiochemical analysis. The presence of fission-product gases in these collected gas samples would indicate a failed fuel element within the capsule, while the absence of such fission-product gases would indicate a sound element within the capsule.

Some nonfueled structural materials elements, such as the presently employed EBR-II in-reactor creep elements which are internally pressurized with an inert gas, may be punctured in order to determine changes in internal pressure in the element resulting from reactor service. These changes in pressure are used in the calculation of element cladding material creep and creep property-changes which have resulted from fast-neutron irradiation and reactor service. The above puncturing and gas collecting operations will be carried out using a fission-gas measuring system to be located in the HFEF/N Main Cell.

b. Metallographic Sample Preparation and Examination

Fueled and nonfueled capsules and elements and other irradiated components will be subjected to metallographic sample preparation and examination operations. Metallographic samples will be prepared by means of remote cutting, mounting, grinding, polishing, and etching operations in

the in-cell containment box located at station 2M in the Main Cell. Following these sample preparation operations, examination of the prepared specimens will be carried out with a remotely operated, shielded optical metallograph. This gastight metallograph, with its gastight shielded enclosure (metallograph loading box) is located in a laboratory (Metallograph Room, No. 123) across the north operating corridor from the Main Cell. Transfer of samples between the in-cell containment box and the metallograph loading box is accomplished by use of a gastight and shielded pneumatic transfer system.

This remote metallography capability in the HFEF/N will make it possible to obtain important metallurgical data pertaining to irradiated fuels and materials microstructural analyses, failure investigations and analyses, materials compatibility, and other metallurgical areas which are important in the assessment of the effects of fast-neutron irradiation and reactor service on fuels and materials.

In order to provide similar metallography support services for work involving nonirradiated fuels, materials, and components, the metallographic laboratory (Room 125) is available adjacent to the metallograph room. This laboratory is also used in direct support of the "hot" metallography operation through its utilization for operator training and in the development of techniques and equipment necessary for successful remote metallography.

The photographic laboratory (Room 121) is used to provide necessary photographic support for both the "hot" and "cold" metallographic operations. In addition, it provides the overall photographic processing requirements of other HFEF/N and HFEF/S hot cell examination equipment and operations (for example, the photographic processing requirements associated with the hot cell periscopes and stereomicroscopes, neutron radiography, etc.).

c. General Machining (milling and cutting)

Fueled and nonfueled capsules and elements and other irradiated components will be reduced in size or cut into specimens for subsequent examinations and tests. This cutting will be carried out with the general-purpose machining equipment located at station 11M in the Main Cell. A numerical-controlled milling machine and a rotary cutoff saw and other miscellaneous cutting equipment will allow for various experiment disassembly operations necessary during examination procedures and for the cutting of specimens intended for subsequent examinations and analyses (for example, metallographic examination, radiochemical analyses, mechanical testing, etc.).

These listed examinations and tests and capabilities are those which comprise the initial HFEF/N capabilities intended to carry out destructive-type postirradiation examinations on the various types of LMFBR fuels and materials experiments.

3. EBR-II Reactor Support Services

The HFEF/N will also be used to carry out preplanned and emergency-type handling operations and examinations of highly irradiated EBR-II components. Such handling operations and examinations could become necessary in order to support sustained operation of the EBR-II, or they may become necessary to support required reactor maintenance or repair operations.

The miscellaneous handling and examination capabilities of HFEF/N, along with its argon-atmosphere Main Cell, could conceivably be utilized to accommodate highly irradiated EBR-II components where relatively large-size components are involved and where significant quantities of sodium are encountered. In this latter case, the inert atmosphere (argon gas) provided by the Main Cell may be a significant advantage over other air atmosphere hot cells because of its inertness to the sodium.

All HFEF/N nondestructive and destructive examination capabilities and other capabilities identified earlier in this report section which would be pertinent to such reactor support activity would be made available to this type of effort.

4. Loop-handling Operations

This section presents a description of the loop-handling methods available at the HFEF/N. Handling operations (receiving, charging, disassembly, examination, disposal and reuse) for both large and small packaged loops are discussed.

There are three major paths by which loops can be charged into the HFEF/N Main Cell: (a) through roof penetrations; (b) into the Decon Cell from the cask tunnel and into the Main Cell through the transfer lock; and (c) from the cask tunnel. A loop is considered large when it is too big to be charged into the cell complex through the cask tunnel.

a. Large Loop Transfers

Transporters bearing casks containing loops are backed into the truck lock upon their arrival from the test location (ETR, TREAT, PBF, FTR, etc.). The transport equipment must be positioned entirely within the building and the truck door closed before the unloading operation can be performed. The building pressure balance will be upset if this door is not closed before the transfer hatches are opened.

Interlocks exist on the truck lock floor hatch and the doors to the entrance to the cask tunnel and they are being installed on the truck door to prevent an imbalance of pressure between the truck lock area and the building or Decon Cell ventilation areas. The doors from the operating corridor and the truck lock are posted to prevent them from being left open. The interlocks will be tested on a bimonthly basis.

When the cask and loop are inside the building, the required utilities are supplied by building services, e.g., pump power, heater power, instrumentation readouts, etc.

When the loop is large and must be introduced into the Main Cell through roof penetrations (see Fig. II-1) special procedures are used. The truck lock roof hatches are removed just prior to transfer of the cask to the high bay, and the high-bay crane may be attached to the cask while it is in the horizontal position. The transporter provides the rotating motion to lift the cask to the vertical position. The cask is lifted 30 ft to the high bay by the crane. As soon as possible, the high-bay hatches are replaced and the transporter moved outside of the building.

Fig. II-1. Transfer System through Loop Insertion Cell. ANL Neg. No. 103-A12249.

The cask is transferred to the top of the loop insertion cell (LIC). The bottom surface of the cask is sealed to the LIC to prevent air in-leakage and contamination out-leakage. Then the crane may be detached from the cask because the LIC top and superstructure are designed to support it even during a Zone 3 earthquake. Cask tiedowns may be required.

The cask loop supports are retracted to assure that they are not supporting the loop and the cask hoist load cell is checked to assure that the hoist is supporting the loop before the shield door is opened. When loop support is assured, both the cask shielding door and the LIC roof hatch are opened. The LIC and cask are now purged with fresh argon to remove all air. The purge enters the cask at the hoist drive and flows down through the cask into the LIC. Upon completion of the argon purge the LIC bottom

hatch is opened and lowering of the loop is started. A suitable argon flow, similar to the purge flow, is continued to reduce the possibility of internal contamination of the cask from the cell. A gross gamma scan of the loop is performed as required during the insertion to determine the approximate fuel dispersion. The cask load cell and other readouts are closely monitored during loop insertion.

The loop is lowered through the loop disassembly machine into a heater which is supported by this machine. When the loop reaches the fully inserted position the cask grapple is disengaged and retracted into the LIC. After retraction of the grapple, the lower hatch of the LIC is closed and the grapple checked for contamination. If significant contamination is found, the grapple will be disconnected and lowered into the Main Cell with the LIC hoist for subsequent decontamination.

b. Small Loop Transfers

To introduce small loops into the cell complex, the truck lock roof hatch directly over the cask tunnel hatch is opened and the crane attached to the cask. The transporter is moved off the tunnel hatch as soon as the cask is supported by the crane. The tunnel hatch is opened and the cask is lowered approximately 10 ft and deposited upon the cask transfer cart. The tunnel can accommodate casks up to approximately 16 ft long. Both the tunnel and truck lock hatches are closed as soon as the crane is retracted to the high bay and the transporter moved outside the building.

If the small loop is to be introduced into the Decon Cell, the transfer cart positions the cask below the Decon Cell transfer penetration and elevates the cask to mate with the tunnel roof. Inside the Decon Cell, the penetration shielding plugs are removed and a grapple is attached to the crane or overhead manipulator depending upon the loop and fixturing weight. The cask shielding door is opened and the loop hoisted into the cell and deposited in the large lock transfer mechanism for transfer to the Main Cell. The penetration shielding plug is replaced and the cask lowered from the tunnel roof. The cask is decontaminated as required and transferred to a storage area with the transporter.

If the small loop is to be introduced directly into the Main Cell, the transfer cart positions the loop cask below the Main Cell transfer penetration and elevates the cask, and a seal is made with the penetration. The shield door is opened and the gastight cask is purged with argon to remove air. Inside the Main Cell the penetration shield and seal plug are removed and the grapple is attached to the crane or overhead manipulator, depending upon loop and fixturing weight. The loop is hoisted into the cell and deposited at the appropriate work station. The penetration shielding seal plug is replaced and the cask purged with clean air to remove any contaminated argon. The cask is lowered from the tunnel roof, decontaminated as necessary and transferred to a storage area.

c. Large Loop Disassembly (without reuse)

The following procedures are used to disassemble a large loop which will be discarded and not reused. Utility lines are connected to the large loop as soon as it is received in order to keep the sodium coolant in the liquid state. Normally, when a loop is received the sodium will be liquid; however, if the sodium is solid, it will be remelted with a heater provided within the cell. The heater is also used to keep the sodium molten during disassembly, since the large loops do not contain heaters.

Appropriate gas samples are obtained prior to disassembly. Then the top closure of the loop is unbolted and a grapple attached. A load cell and the overhead manipulator are attached to the grapple and lifting of the test train is started. The test train is lifted to an appropriate elevation where it is secured and cut apart. The cut section is removed and the remaining section is again lifted, secured and cut. This operation is repeated until the entire test train is removed from the loop. Load readings are monitored during each lift to determine whether the test train is sticking within the loop during removal. The test train sections are placed in storage pending examination.

After the test train has been removed the sodium in the loop is kept fluid with the assistance of the heater. Then the sodium is pressurized out of the loop and into a storage tank which contains a filter.

Disposal of the large loop is accomplished by cutting it into pieces small enough to fit into $1\frac{3}{4}$ -in. ID by $5\frac{1}{2}$ -ft-long waste cans, which hold about 250 lb each. Thus, it requires upwards of 40 waste cans to dispose of one large loop.

Special machines are provided to cut the loop into sections which can be manipulated with the equipment in the cell. These sections are then cleaned of sodium and fuel materials. Each large section must then be dissected into disposable-size pieces. These pieces are transferred to the Decon Cell and the waste disposal system described elsewhere in this document.

d. Small Loop Disassembly (without reuse)

Small loops are usually received with the sodium coolant in the solid state and they usually contain their own remelt heaters. The loop is transferred into the Main Cell through the Decon Cell or directly into the Main Cell and placed in a disassembly support structure. The sodium in the loop is remelted by means of the internal heater, and gas samples are obtained as required. Test trains from small loops can be removed as one

piece but in some cases it may be desirable to cut the train as described for large loops. The test train is placed in storage to await examination.

There are two methods available for removal of sodium from small loops. The first is identical to that described for large loops. The second involves attaching a catch tank to the top end of the loop, upending it, and allowing all sodium to drain into the catch tank.

Disposal of small loops is similar to that described for large loops except that very few cutting operations are required. Usually only one or two cuts are needed to reduce the loop into sections which can be handled by the disposal system.

e. Disassembly of Test Trains

There are three separate ways to disassemble test trains:

- (1) by means of special fixtures with the motions available on the vertical assembler-dismantler.
- (2) by means of the milling machine and special fixtures.
- (3) by means of special equipment designed and built to handle any specially designed test train.

The disassembly of a test train is a very slow operation, each step is evaluated and may be photographed as the operation progresses.

Disassembly in the vertical assembler-dismantler involves placing the test train into the machine in a vertical orientation. The hex can is cut below the grid piece and pulled up and off the fuel pins. Clamps are placed around the fuel pins as they are exposed as the hex can slides off. It is also possible to split the hex can at the VAD and remove the can in sections. Examination of the fuel bundle and removal of fuel pins are performed with the fuel in a vertical position.

A milling machine disassembly involves placing the test train in a horizontal position on a mill table with appropriate fixtures. Appropriate cuts are made to remove the hex can from the pins. Various clamping fixtures are provided to assist the disassembly. There are several cutting sequences developed for the disassembly of EBR-II failed fuel subassemblies. Examination of the fuel bundle and removal of fuel pins are performed with the fuel in the horizontal position.

Special equipment disassembly can be described only when complete procedures are developed for the disassembly of a particular specially designed assembly.

f. Procedures for the Reuse of Loops

Reuse of loops after removal of the test train involves the elimination of contamination, especially from the exterior surfaces. Techniques have not been fully developed to date, but several concepts are presented below.

For a large loop, it is possible to insert the loop into a can as it is being discharged from the cask. The can is supported in the LIC and a remote seal made between the can and the loop. All loop disassembly operations described earlier are performed as presented.

The can is disconnected from the loop upon its removal from the cell and while it is still in the LIC. Only the exterior of the top closure of the loop is subject to contamination and this area is decontaminated while it is within the LIC.

Short, small loops can be put into the Decon Cell clean room. A new can is then placed in the loop cask and the loop lowered into the can. Appropriate seals are made and the loop is charged into the facility as described previously. Canning does not affect test train or sodium removal or examination.

After the examination is completed, the canned loop is transferred to the Decon Cell work station and given a good cleaning. The can is removed from the loop just before the loop is removed from the cell. The surfaces of the loop should not become contaminated during this last step, but if they do, contamination will be minute and can be removed during refitting.

A special charging technique can be used in which the top end of the loop is drawn up into the Decon Cell clean room where it is fitted with a special collar that has an inner and outer ring connected by an annular bellows. The inner ring is designed to seal to the top end of the loop and the outer ring to the tunnel roof making a gastight seal. The loop is lowered back into the cask and the cask is transferred to the Main Cell penetration. The cask is elevated so that the outer ring makes a seal at the tunnel roof, and the area above the collar is purged with argon. The shield seal plug is removed from the Main Cell penetration and the loop is raised up into the cell just far enough to perform the required operations. A hoist system in the cask beneath the loop is utilized to provide the vertical motions.

After disassembly operations are performed, the loop is lowered back into the cask and the shield seal plug replaced. The loop is now transferred to the Decon Cell charging port and elevated into the cell. The loop-to-collar seal is broken and the loop lowered back into the cell. Only the test train closure has been exposed to a contaminated environment and this can be cleaned before removal from the Decon Cell.

g. Examination of Loop Components

Components from both large and small loops can be disassembled for examination with the equipment provided at the general machining station. Additional disassembly equipment will be provided as special problems arise. Examination equipment will be provided to meet requirements for the type of examinations called for.

h. Sodium Examination and Disposal

As mentioned previously, the sodium is pressurized out of a loop and into a storage tank containing a filter.

The filter and sodium samples are removed from the system and transferred to the examination location. Fuel-particle examination requirements or techniques have not yet been established. Sodium samples will be sent to the chemistry group for examination.

Sodium from the loops will be transferred from the collection system storage tank to storage containers as soon as sodium examination work is completed. The containers will be sealed and stored in the area below the steel floor of the Main Cell pending disposal. The sodium will be transferred out of cell in sealed containers and transferred to interim storage in a manner and location to be determined.

i. Remote Assembly of Test Trains

Many test trains will require remote assembly since they will contain fuel pins which have been irradiated previously. Some of these fuels will be specially fabricated for remote assembly, while others will have been selected from standard reactor fuel subassemblies for loop testing.

There are two basic types of remote test train assembly: (1) test trains with no instrumentation on the preirradiated fuels; and (2) test trains with instrumented preirradiated fuels.

A test train assembly with noninstrumented preirradiated fuels will be of the plug-in type. A plug-in type test train is completely assembled outside the hot cell and then charged into the cell where the preirradiated fuel pins are inserted (plugged-in) and latched in place.

Care must be taken to prevent contamination of the loop closure of the plug-in type test train. The contamination is prevented by canning or bagging and the can or bag is removed as the test train is removed from the hot cell. Removal of the test train from the hot cell is performed using the same type of procedures developed for loop receiving but only in the reverse order.

Assembly of a test train with instrumented preirradiated fuels comprises three major operations: (1) instrumentation of the fuel pins; (2) assembly of the test train; and (3) assembly of the top closure and hookup of instrument leads. The application of instrumentation to fuel pins may include only attachment of the instrument, but in many cases, it includes the modification of the pin. Thermocouples, strain gauges and pressure sensors are the usual instruments applied to fuel pins. Assembly of test trains with instrumented preirradiated fuel is a difficult task. Special equipment is required to hold, position, weld, etc., the fuel and train structural components. Long trains must be assembled in the vertical position while short trains can be assembled in a horizontal orientation. Remote assembly of a test train top closure and the hookup of instrumentation leads is presently beyond the state of the art. In order to perform the final operation, the test train must be placed in a shielded pit or container with the top end protruding. Personnel may then work around the top closure with proper procedures and shielding provided to limit personnel exposures.

j. Remote Assembly of a Test Train into a Loop

The remote assembly of a test train into a loop can be performed in either the Main Cell or Decon Cell depending upon whether or not exposed sodium is present. Remote assembly usually will require utilization of the loop-canning techniques described earlier.

The canned loop is charged into the cell and the test train is slowly inserted utilizing the various cell equipment or special equipment to be provided. The loop may then be filled with sodium, or this operation can be performed after removal from the cell.

Contamination of the exterior surface of the loop is a problem with this type of operation. Every effort is made to prevent contamination; however, methods are available for decontamination if it becomes necessary.

B. Emergency Plan

This section summarizes the general emergency plan for the Hot Fuel Examination Facility, including the organization and responsibilities of emergency personnel, preparation of emergency procedures, training and drill requirements, emergency signals, emergency equipment availability and control, methods of accounting for personnel, communication systems, safety guidelines, medical assistance, and reentry guidelines. More specific details and information are contained in the "HFEF Emergency Plan and Procedures."

Emergency planning for HFEF covers all buildings affiliated with the facility; i.e., Buildings 765 and 765A (HFEF/S), Building 785 (HFEF/N), and Temporary Building T-8.

1. Organization and Responsibilities

a. HFEF Manager

The HFEF Manager has overall responsibility for safety, including emergency preparedness, of the HFEF complex. He reports directly to the ANL-West Site Manager.

b. HFEF Emergency Planner

The "emergency planner" is an HFEF staff employee who has been assigned the responsibility for preparation and coordination of the "HFEF Emergency Plan and Procedures" and for implementing the directives of the "Idaho Site Emergency Plan." The emergency planner is also responsible for coordinating the training of facility personnel in emergency procedures and for the procurement and maintenance of emergency equipment for the facility.

c. HFEF Emergency Directors

An "emergency director" is an HFEF supervisory staff employee who has been assigned the responsibility for the implementation of HFEF emergency procedures and is in charge of facility emergency personnel and reentry planning. For the HFEF complex, one emergency director is assigned to HFEF/N and another to HFEF/S and Temporary Building T-8. Also, "alternate emergency directors" are assigned on the same basis.

The emergency director has prime responsibility for HFEF emergency actions within the facility of assigned responsibility and is in charge of the facility during an emergency.

He remains responsible until he is relieved by higher authority or until such time that the emergency extends beyond the boundaries of the facility and he is relieved of authority by the Site Emergency Director. Responsibilities of the emergency director include evacuation of personnel from the facility, facility shutdown, rescue of injured personnel, and other action warranted by the conditions of the emergency. The specific responsibilities of the emergency director are detailed in the HFEF emergency procedures. The emergency director and alternate emergency director will be thoroughly familiar with all aspects of operations in the facility to which they are assigned.

The HFEF shift supervisor assumes responsibility for facility emergency actions in the absence of the regular emergency director and alternate emergency director during an off-shift period when scheduled personnel are within the HFEF complex. In the event of an emergency during

an off-shift period when no personnel are scheduled to be within HFEF, the Site Emergency Director (EBR-II shift supervisor) assumes responsibility for emergency actions.

d. HFEF Area Wardens

"Area wardens" are HFEF personnel who have been assigned the responsibility of assuring the evacuation of personnel within designated areas of HFEF facilities in a declared emergency. Specific instructions for the area wardens are detailed in the HFEF emergency procedures. The area wardens' and alternate area wardens' names and locations of their respective areas of responsibility will be posted in the HFEF complex. A "chief area warden" is assigned to HFEF/N and another to HFEF/S and Temporary Building T-8 for daily accountability of area wardens and assistance to the emergency planner in training. Alternate chief area wardens are also designated.

In the event of an emergency during an off-shift period when scheduled personnel are within HFEF, available area wardens will perform their specified functions. In the absence of regularly assigned area wardens, the HFEF shift supervisor assumes their responsibilities, using the best means available to him consistent with the conditions of the emergency and personal safety.

e. HFEF Chief Technicians

"Chief technicians" are supervisory personnel for HFEF operations. In an emergency situation, the chief technicians are responsible for assuring the necessary emergency shutdown of special equipment or systems under their cognizance. For fire emergencies, the chief technician assigned to the affected facility provides firefighting support as outlined in the emergency procedures. The chief technicians will receive special training in emergency reentry of the facility and will be the lead personnel in facility reentry teams.

f. Radiation Safety Personnel

Radiation Safety technicians working within HFEF are assigned by and report to the Manager, Radiological Engineering. They are responsible, in general, for providing guidance and control of all personnel in order to prevent or minimize overexposure from penetrating radiation of radioactive materials. In an emergency situation, Radiation Safety personnel are responsible for monitoring the area or facility and advising the emergency director of existing or potential radiation hazards. Specific instructions for the Radiation Safety personnel are detailed in the emergency procedures.

In the event of an emergency during an off-shift period when no scheduled personnel are within HFEF, EBR-II Radiation Safety personnel will accompany and support the Site Emergency Director in emergency actions that may involve radiation hazards. This will include investigation of fire, radiation, and nuclear criticality alarms.

2. Preparation of Emergency Procedures

HFEF emergency procedures are prepared by the emergency planner, implementing the requirements and objectives of the "HFEF Emergency Plan" and "Idaho Site Emergency Plan." The minimum requirements for HFEF emergency procedures shall cover the occurrence or the imminent occurrence of each of the following conditions:

- Fire, smoke or explosion
- High radiation
- Accidental nuclear criticality
- Uncontrolled radioactive airborne contamination
- Flooding, failure of building structural components, release of harmful liquids or gases, and other miscellaneous emergencies
- ANL-West area alert or evacuation.

The specific HFEF emergency procedures include consideration of the following:

- Initiation of an emergency alarm
- Action to be taken by facility personnel
- Action to be taken by special-equipment and system operators
- Action to be taken by emergency personnel
- Special conditions or constraints to be followed.

The "HFEF Emergency Plan and Procedures" will be reviewed and updated annually, at a minimum, by the emergency planner. Revisions, or statements assuring that the existing plan and procedures meet current regulatory requirements and are responsive to the special problems of HFEF are to be prepared, approved, and submitted to the ANL-West Site Manager and HFEF Manager annually.

3. Training and Drills

All personnel normally working in the HFEF complex are indoctrinated on HFEF emergency and evacuation procedures and site evacuation procedures. The training program includes the indoctrination of new

employees and an annual review of emergency procedures with all employees. The emergency planner is responsible for coordinating this training.

Off-site personnel, such as contractors, visitors, etc., who will be in the HFEF complex more than five working days will be indoctrinated in HFEF emergency and evacuation procedures and site evacuation procedures. Such training is the responsibility of the emergency planner. The supervisor of the area assumes responsibility for the safety of any off-site personnel who have not been indoctrinated in emergency procedures.

The service personnel who work in the facility on off-shift hours have received individual instruction on actions to be taken in case of an emergency in the facility.

The emergency planner is responsible for providing special training and instruction to those personnel who are assigned emergency-action tasks. This special training includes the instructions and responsibilities of the emergency director, area wardens, and Radiation Safety personnel assigned to HFEF. Emergency personnel will be thoroughly indoctrinated on any revisions of the "HFEF Emergency Plan and Procedures."

Operators of special equipment or systems will be trained by the responsible supervisors in procedures to be followed in emergency conditions. These emergency procedures are documented in the HFEF Operating Manual sections for the respective equipment or systems.

Operators that may have occasion to use fire extinguishers must be familiar with the location of fire extinguishers in the area and the proper use and restrictions of each type. The supervisor of the area is responsible for this training, which is monitored by the emergency planner.

A test of the emergency evacuation procedure is to be made at least once annually. Emergency tests will be conducted in accordance with Appendix L, Idaho Site Emergency Plan. The emergency planner and emergency director will review these tests in detail and take appropriate action, if necessary, to improve HFEF emergency procedures and make recommendations to improve the overall emergency preparedness of ANL-West.

4. Facility Emergency Signals

a. Facility Fire Alarms

Manual fire-alarm boxes are located in HFEF/S and HFEF/N. Actuation of a manual fire-alarm box results in a coded bell alarm being transmitted throughout ANL-West (except TREAT), and to the INEL Fire Department, Station No. 3.

The entirety of HFEF/N, excluding the Main Cell and Decon Cell, is protected by heat detectors and photoelectric detectors. Also, automatic sprinkler systems are installed in the HFEF/N truck lock and emergency generator room. Actuation of any of these systems automatically initiates the coded bell-alarm system for HFEF/N. The alarm actuated, including manual fire-alarm boxes, is annunciated at an indicating unit located in the corridor of the southeast corner of the operating floor, an auxiliary indicating unit located at the northwest stairwell, and the operations control room. A total of 16 stations or zones are annunciated.

No fire detection devices are installed in the Decon Cell. Ionization-type smoke or flame detectors are not used because they are susceptible to failure as a result of the high radiation fields. Rate-of-temperature-rise detectors were not thought to be practical because of the large temperature fluctuations that would result from loss of illumination caused by a power failure and because there are no large sources of combustible material in the cell which could cause a heat source large enough to activate such a detector.

An automatic sprinkler system in the HFEF/S truck decon room automatically initiates the coded bell-alarm system when actuated.

A fire may be reported by Dial 13 to the Special Services operator or by telephoning INEL Fire Station No. 3, Extension 7233, or Central Fire Alarm Headquarters, Extension 2211. Reporting a fire by telephone brings immediate response from INEL Fire Station No. 3 at ANL-West and initiates action from other AEC-INEL fire units for additional support as required.

b. Facility Radiation Alarms

Gamma monitors and air monitors are located in HFEF/S and HFEF/N. Building evacuation is initiated automatically if a predetermined activity level is exceeded in the vicinity of a monitor.

Actuation of a radiation monitor will cause an intermittent horn-alarm to be sounded plus a broadcast on the building public address system of a prerecorded message stating that the building should be evacuated. Actuation of a radiation monitor is annunciated at the building operations control room, the Radiation Safety office, and the EBR-II power plant. The radiation monitors are connected to the building emergency power system in the event of loss of site electrical power.

Criticality-type gamma monitors are located in HFEF/N and HFEF/S. These monitors are automatically activated in the event of nuclear criticality in the area. The electrically operated components of the criticality detection and alarm system are powered by nickel-cadmium battery stations to assure operation in the event of site power failure.

Initial locations of radiation detectors in the high-bay area are the center of west end (gamma monitor) and south side opposite suspect repair room (gamma, beta-gamma air particulate, alpha air particulate, criticality monitor). Initial locations of radiation detectors in the remainder of HFEF/N are shown on pp. 3.3, 3.5 and 3.6.

Activation of a criticality monitor will cause a pulsating signal horn to be sounded and a rotating blue-colored light associated with the monitor to be activated. Activation of any monitor will cause all alarm horns in that building to be sounded but only the alarm light at the monitor area that exceeds its alarm setpoint will be actuated. Pulsating signal horns and rotating blue-colored lights are also located on the outside near the entrance doors. The actuation of any criticality monitor will cause a prerecorded message to be announced on the all-call telephone system stating the area where the incident occurred and emergency instructions.

c. Facility Off-standard Alarms

An off-standard condition involving process systems equipment in HFEF/N is automatically annunciated at the operations control room of the building (with slave alarms in all parts of the building) and during "off-hours" at the EBR-II power plant. Abnormal discharges from the HFEF/S or HFEF/N stack monitoring system are automatically annunciated at the operations control room and the Radiation Safety office of the affected building (with slave alarms in all parts of the affected building) or at the EBR-II power plant. The HFEF/S stack monitors check the discharge air and other gases from the EBR-II reactor building, laboratory and office building, and HFEF/S for abnormal discharges of gross particulate activity, sodium-24, gross gas activity, argon-41, and iodine-131. The HFEF/N stack monitor checks for abnormal discharges of gross alpha and beta particulates, ^{131}I , ^{137}Cs , ^{85}Kr , ^{133}Xe , and gross gas activity.

Airborne contamination in excess of a predetermined activity level will activate the air monitor located in the manipulator decontamination and repair area, HFEF/S second floor, and cause an intermittent horn-alarm to be sounded in the area. This is a local alarm and is not annunciated.

d. Site Emergency Alarms

The "alert--take cover" signal is a continuous siren signal lasting not less than three minutes, which may be preceded by an emergency announcement and instructions over the public address system.

The "evacuate" signal is an oscillating siren signal lasting five seconds "on" and five seconds "off" for not less than five minutes.

The evacuate and alert--take cover alarms can be activated from HFEF/S or HFEF/N through a station located in the corridor at the main entrance to each building.

5. Emergency Equipment and Supplies

a. Facility Fire-fighting Equipment

The portable fire-fighting equipment available within HFEF facilities is as follows:

- Water or antifreeze fire extinguishers for use on wood, textile, paper, rubbish or other ordinary combustible material fires.
- Carbon dioxide, dry chemical, and Met-L-X fire extinguishers for use on flammable liquid or grease fires and live electrical equipment fires.

A carbon dioxide fire extinguishing system is available in the HFEF/N Decon Cell and Cask Tunnel. The system in the Decon Cell can be operated remotely to extinguish the largest postulated fire of 500 ml of alcohol or an electrical fire in any single zone. The potential for a sodium fire is extremely remote in either area, since the nominal quantity (approximately two liters) of sodium that might be exposed will be inerted with argon gas. A sodium fire involving this quantity would not plug the filtration system. In the Decon Cell, a sodium fire could be extinguished remotely with an approved dry chemical (e.g., white silica sand) provided in the cell. Special fire protection for SLSF loops will be addressed in the SLSF Addendum.

A Halon 1301 fire extinguishing system is installed in the operations office and DAPCS computer room.

Automatic sprinkler systems are installed in the HFEF/S truck decon room, in the HFEF/N truck lock and emergency generator room, and in Temporary Building T-8.

b. Emergency Equipment Cabinets

Emergency equipment cabinets are located on the main floor and in the basement of HFEF/S and on the service floor, operating floor, and high bay of HFEF/N. These cabinets contain tools and protective equipment for firefighting and other emergencies.

c. Portable Radiation Monitoring Equipment

The Industrial and Radiation Safety office in HFEF/S and HFEF/N maintains portable radiation monitoring equipment for everyday use and emergency conditions. The minimum inventory of such equipment includes the following:

- Four 0-25 R/hr Juno survey meters
- Four 0-200 mR/hr Geiger-Mueller survey meters
- One 0-200,000 count/min alpha-scintillation-type meter.

Each emergency director and area warden carries on his person during working hours a personal radiation monitor which gives a variable audible signal dependent on the levels of gamma radiation encountered. In an emergency, the personal radiation monitor is used as a guide in evaluating radiation exposure as a supplement to radiation safety surveillance and during any period when radiation safety surveillance is not available.

d. Nuclear Accident Dosimeters

Criticality dosimeters are located in HFEF/S and HFEF/N as follows:

- HFEF/S first floor, cabinet by transfer port
- HFEF/S precision measurements lab, Room 26
- HFEF/S loading dock area, south wall
- HFEF/S basement, post by retention tank area
- HFEF/S passageway
- HFEF/N service floor, retention tank area
- HFEF/N operating floor, metallography room area
- HFEF/N high bay, hot repair room area
- HFEF/N operating floor, west wall

e. Protective Clothing

A supply of protective clothing for everyday use is maintained in HFEF/S and HFEF/N. This supply includes coveralls, shoe covers, plastic bags, underwear, socks, skull caps, hoods, rubber gloves, and filter-type full-face respirators.

f. First Aid Kits

A first aid kit, available in the Radiation Safety office in the HFEF/S and HFEF/N, contains supplies for emergency use.

g. ANL-West Emergency Supplies and Equipment

Supplies of material and equipment available for use in emergency conditions at ANL-West are summarized in Appendix H, Idaho Site Emergency Plan.

6. Communication Systems

The HFEF buildings have telephone service and a public address system for normal and emergency communication. Emergency power for telephone service is provided by a battery system located in the Laboratory and Office Building. The public address system for HFEF/S and HFEF/N is connected to the respective building emergency power supply for operation in the event of a site power failure.

Communication facilities at ANL- West include commercial telephone, Federal Telephone System, teletype, and facsimile systems, together with an elaborate radio network. These systems are further described in Appendix I, Idaho Site Emergency Plan.

7. Emergency Communications

a. Facility Emergency Communications

The emergency director or any other person who notices a situation or condition justifying emergency notification of facility personnel has the authority to initiate an emergency alarm. Personnel within the facility will be notified of the emergency condition and the action to be taken by use of the public address system for emergencies not covered by specific alarm systems (fire alarms, evacuation alarms, etc.). Procedures for initiating emergency alarms are discussed in the specific emergency procedures.

In a declared emergency, the telephone system, including public address, is reserved for emergency use. At such time personnel must not use the telephone system for calls other than those of an emergency nature as authorized by the emergency director.

The facility "all-clear" announcement will be a voice announcement by the emergency director or other means of communication as appropriate to the emergency. Guidelines to be followed prior to issuing the "all-clear" announcement are given below.

b. ANL- West Area Communications

A facility emergency that jeopardizes or potentially jeopardizes the safety of personnel or property in the ANL- West area will be communicated through the initiation of the site "evacuate" or "alert--take cover" alarms. These alarms normally should not be activated unless authorized by the Site Emergency Director through communication by the Dial 13 system. If the alarm is activated for due cause prior to notification of the Site Emergency Director, the responsible person reports to him, as soon as possible, the details and reasons for the action.

For all HFEF facility emergencies, the HFEF emergency director for the affected building establishes communication with the Site Emergency Director (Dial 13) as soon as possible to keep him advised of conditions.

The HFEF emergency director remains in charge provided the emergency condition is confined to the facility. If the emergency condition threatens areas outside the facility, the Site Emergency Director takes command of site emergency actions.

For HFEF facility emergencies during an off-shift period, the cognizant person, HFEF shift supervisor or EBR-II shift supervisor, notifies appropriate ANL personnel by telephoning them personally or by requesting that Special Services (EBR-II guard post) call them. The HFEF management will provide guidance in determining emergency actions to be taken and will report to the site as appropriate to the conditions of the emergency and personal safety.

8. Testing and Maintenance

The emergency planner has the responsibility for coordinating and monitoring the testing and maintenance of emergency signals and emergency equipment within the HFEF complex. Specific responsibilities are outlined below.

a. Fire Alarms

The testing of HFEF fire alarms is the responsibility of the ANL-West fire-protection engineer. Manual fire alarms and automatic detectors are tested bimonthly.

b. Radiation and Criticality Alarms

The Radiation Safety chief technician for HFEF is responsible for the testing and maintenance of HFEF gamma monitors, air monitors, and criticality monitors. Testing and calibration of the monitors are performed by the EBR-II instrument shop on a six-month minimum schedule.

c. Alert--Take Cover and Evacuate Alarms

Special Services is responsible for the ANL-West alert--take cover and the evacuate alarms. A different station is checked each Sunday with the HFEF alarms checked every seven weeks. Necessary maintenance work on the alarms is done by Plant Services.

d. Fire Extinguishing Equipment

The ANL-West fire-protection engineer is responsible for testing and maintaining HFEF fire extinguishing equipment. The fire extinguishers are checked monthly. The fire hose stations and automatic sprinkler systems will be checked annually.

e. Emergency Equipment Cabinets

The cabinets and equipment contained within are the responsibility of the ANL-West safety engineer. The cabinets and equipment are checked monthly. The cabinets are sealed so that the seal will be broken if the cabinet is opened. After a cabinet is used, the safety engineer will be contacted by the emergency planner to inventory the equipment, restock the cabinet, and reseal it.

f. Portable Radiation Monitoring Equipment

The chief technician for HFEF Radiation Safety is responsible for HFEF portable radiation monitoring equipment. The monitoring units are checked and, if necessary, replaced weekly. The portable radiation monitoring equipment, except personal monitors, is on a six-month maintenance and calibration schedule.

g. Nuclear Accident Dosimeters

Criticality dosimeters are supplied and maintained by the Health Services Laboratory, Idaho Operations Office. Dosimeters are inspected every two years by this laboratory.

9. Personnel Accountability

Personnel accountability in an emergency is based on an area-warden system. This system provides an area warden and an alternate area warden for each area of the HFEF complex. The area warden is responsible for surveying his area of responsibility to assure that all personnel have evacuated in a manner appropriate to the declared emergency. Instructions for the area wardens are detailed in the specific emergency procedures. The emergency planner is responsible for establishing and maintaining the area-warden system. Training of the area wardens is the responsibility of the emergency planner with assistance from the chief area wardens.

The presence of the area warden for each area is determined each normal work day. In the absence of the area warden, the alternate area warden will be notified. In the absence of both the area warden and the alternate area warden for an area, an alternate area warden from an adjacent area will be assigned as temporary area warden for the area. The chief area warden of the building will be responsible for the daily assignment of area wardens.

Facility personnel must maintain their identity film badges on their person while in the ANL-West area and during a site evacuation. Controls and accountability of personnel by identity film badges in an emergency will be as outlined in Appendix K, Idaho Site Emergency Plan.

10. Safety Guidelines

Guidelines to be used for radiation exposure and personnel protection under emergency conditions will be in accordance with Appendix A, Idaho Site Emergency Plan. The emergency director has the responsibility for assuring adherence to these guidelines.

Action levels in accordance with Appendix B, Idaho Site Emergency Plan, are to be applied by the emergency director in determining if a given emergency situation warrants facility or ANL-West area evacuation. Personnel will follow posted evacuation routes in a facility evacuation. Obvious danger zones will be avoided whenever possible. This includes areas of local damage, fire, smoke, and any area where a radiation monitor beacon is flashing.

Safeguarding of facility equipment and systems in accordance with preestablished emergency shutdown procedures will be secondary to personal safety if such a decision is necessary.

11. Medical Assistance

First aid service is available during the normal working hours from the ANL-West Dispensary, Extension 7219 or Dial 13. In the absence or incapacity of the ANL nurse, Special Services representatives and certain radiation safety technicians are trained first aid personnel. First aid service is also available from the INEL Fire Department if the firemen are not required to cope with the emergency.

Ambulance service is available through the INEL Fire Department, Station No. 3, Extension 7233 or Dial 13. The need for medical treatment and personnel decontamination services available at Central Facilities Dispensary, INEL, will be coordinated by the emergency director.

Arrangements have been made with off-site hospitals to provide supplemental services in event of a major emergency involving more personnel than the Central Facilities Dispensary, INEL, can handle. The need for such services will be coordinated by the emergency director per Appendix E, Idaho Site Emergency Plan.

12. Reentry Guidelines

a. Reentry Classifications

Reentry applies to the initial reentry of personnel into an HFEF building after a declared emergency has resulted in the evacuation of personnel from the building. This may be the general reentry of personnel or the limited reentry of emergency teams for purposes of evaluation and measurement of hazardous conditions; control of fire, radiation, and contamination; rescue of injured or trapped personnel, etc.

A Class I reentry is reentry after a known false alarm or minor incident (smoke, water, etc.) that has been controlled.

A Class II reentry is reentry of a limited number of emergency personnel into an HFEF building when an emergency condition is confined to the HFEF.

A Class III reentry is reentry after an emergency that has affected areas beyond the HFEF complex, and a site emergency has been declared.

A Class IV reentry is reentry after a major HFEF emergency or disaster involving extensive fire, radiation levels in excess of 1000 rem/hr, or major damage to the facility.

b. Reentry Planning

(1) Class I Reentry: The HFEF emergency director for the affected building, in consultation with the appropriate specialist personnel (Radiation Safety personnel, INEL Fire Department personnel, safety engineer, etc.) establishes that a dangerous condition no longer exists. Upon such assurance, the emergency director authorizes the reentry of facility personnel by voice announcement.

(2) Class II Reentry: The HFEF emergency director for the affected facility has the responsibility for planning and directing reentry activities. Radiation Safety personnel assigned to the facility have the responsibility for monitoring and providing guidance concerning radiation and contamination hazards in the planning and execution of reentry activities. Additional reentry support is requested by the emergency director from chief technicians assigned to the facility, specially trained for reentry, or other specialized HFEF personnel whose knowledge and experience may be of particular value in accomplishing planned reentry activities. The minimum reentry team consists of one radiation safety technician and two other HFEF employees.

A reentry plan must be formulated by the emergency director prior to the execution of reentry activities. The minimum elements to be considered in reentry planning are as follows:

- Area wardens, chief technicians, and Radiation Safety personnel of the affected facility and any other personnel with pertinent information are to be consulted to assemble all available facts and information regarding the conditions of the emergency.
- Thorough consideration will be given to the emergency equipment and supplies needed by the reentry team.

This includes radiation monitoring equipment, protective clothing, and equipment required per the reentry procedure, Idaho Site Emergency Plan.

- Preplanning will be done to define the reentry activities to be performed. This includes the reentry route to be taken. Members of the reentry team will be thoroughly briefed on their individual assignments and tasks to be performed.

Admittance of personnel other than authorized emergency personnel will not be allowed until the emergency director has issued the "all-clear" announcement. The emergency director, in consultation with the appropriate specialist personnel, establishes that a danger condition no longer exists and obtains concurrence of the HFEF Manager prior to issuing the "all-clear" announcement.

(3) Class III Reentry: The Site Emergency Director is responsible for planning and directing reentry activities. All or a portion of this responsibility may be delegated to the HFEF emergency director of the affected facility as appropriate to the conditions of the emergency.

The reentry personnel may be a site reentry team as defined in the reentry procedure, Idaho Site Emergency Plan, or a facility reentry team as mentioned above, as appropriate to the emergency to best accomplish planned reentry activities.

All of the above-mentioned planning considerations apply, plus those additional considerations commensurate with the type and severity of the emergency.

Specific HFEF Operation and Maintenance Manual sections covering the facility plans and systems may be of value in reentry planning. Copies of these sections are kept in the "Evacuation Control Area" for ready accessibility.

Only those personnel authorized by the Site Emergency Director will be allowed to reenter. Before an "all-clear" announcement is issued a review of all safety aspects is to be made and concurred in by the HFEF Manager and other ANL and ERDA officials as appropriate to the emergency.

(4) Class IV Reentry: A Class IV reentry will normally involve emergencies of such severity that the necessary equipment and capabilities will not be available at ANL-West to allow a safe reentry. Such a situation will require extensive planning and coordination prior to authorization of any reentry.

C. Job and Safety Training

A formal training program must be completed by all HFEF/N technicians who are to operate specific in-cell equipment or various building systems. This training program covers all aspects of safety as well as the individual items of equipment and the various systems.

All newly hired operators and trainees are required to attend orientation lectures covering equipment, procedures, and systems. The HFEF Operation and Maintenance Manual is the primary reference document for all systems and operations in the HFEF complex. It provides the user with either the primary information or a definite reference to the primary source. Information on the following functions is included in the manual: administrative control, training of operating personnel, operation of equipment under normal and other expected conditions, performance of tests to ensure the validity of experimental results and the reliability of support systems, preventive maintenance and repair of equipment, maintenance of adequate safeguards to ensure personnel safety and plant protection, and documentation of emergency plans.

Systems training is normally the responsibility of the chief technician who has been trained in the particular system by the engineer responsible for the development and operation of the equipment. A technician or trainee, upon being assigned to a system, works under the direct supervision of a qualified operator. He will not be permitted to operate equipment without direct supervision until he is fully qualified. When the responsible chief technician has verified to his own satisfaction that the trainee is qualified to operate the equipment, he will sign a qualification sheet. The engineer responsible for the particular equipment item then performs an independent evaluation of the trainee and if he is satisfied with the training, he also signs the qualification sheet. This dual verification is required before the technician is considered trained to operate the equipment without direct supervision. The dual approval system affords the engineer a means of evaluating the training that has been given by the chief technician.

Qualifications are valid for a maximum of one year. Shortly before this period expires, and providing the technician has a continued assignment to the particular system, the chief technician and responsible engineer recheck the individual before signing a new qualification sheet.

A videotape recording system is used to augment the training program. Tapes are made of lectures which must be given repeatedly to different groups of personnel. Tapes are also made to illustrate the principles of operation, and the maintenance and repair of equipment. This is particularly valuable for teaching the handling of equipment which is located within the shielded cells and thus not accessible for training purposes.

To provide the HFEF/N management with a continuously current record of the status of skills of all technicians and trainees, a systems-qualification record is maintained. In addition to providing the current status of the training of each operator, these records assist the operations group in maintaining the necessary number of trained personnel for each system. The record is a file of the forms containing the approval signatures of the system chief technician and the responsible engineer and identifying the system and components which each individual has been qualified to operate or maintain. The qualification record system is maintained by the training supervisor.

All personnel are instructed in the requirement to follow approved procedures, both those included in the Operation and Maintenance Manual and those in the nonroutine procedures. Included in these instructions are the methods by which changes to these procedures are reviewed, approved, and documented.

Training of supervisory personnel for specific equipment responsibilities is accomplished by two methods. For new equipment items, an engineer is assigned responsibility for each item when it arrives at the site. He is responsible for overseeing the assembly and testing of the equipment prior to its installation in the cell. He is also responsible for providing the operating procedures and for writing the pertinent operating manual section. In addition, an alternate engineer is also assigned to the equipment. The responsible engineer has the duty of training the alternate engineer in the operation and maintenance of the equipment so that the alternate engineer may substitute for the responsible engineer when necessary.

On an annual basis, all HFEF/N operators are required to receive updating or refresher instructions in areas of safety. Criticality control instruction is also presented to, and qualification authorized for, those personnel whose work involves the handling of fissionable materials.

All newly hired technicians and technician trainees receive instruction in radiological safety from the HFEF chief technician for Radiation Safety. The scope and length of time spent on this instruction is the responsibility of the chief technician, and is determined by the background and previous experience of each new hire.

On an annual basis Radiation Safety personnel will prepare and deliver pertinent lectures and demonstrations for all HFEF operators; lectures that will provide updating and requalification information. It is the responsibility of Radiation Safety to ensure that all HFEF technicians are trained to the most current standard required by the ERDA.

All technicians whose work assignments involve the use of out-of-cell overhead cranes will receive instruction and be licensed by personnel

from the Industrial Safety group. New hires, prior to starting work assignments, will receive instruction in the proper use of the respiratory equipment maintained in the HFEF/N. Yearly refresher courses in the proper use of respiratory equipment are given to all personnel who have a need for this equipment.

In addition to the above, HFEF supervisory personnel receive training in the specific areas of:

- Facility Emergency Plans and Procedures. This training is the responsibility of the HFEF Emergency Director. Details of the plans and procedures as well as the training requirements thereof are contained in the ANL-West Emergency Plan.
- Nuclear Criticality Safety. The necessary criticality hazards procedures and training requirements are detailed in the General Plan for Nuclear Criticality Safety, Argonne-West, ID-CSGP-G01.
- Facility Operating Rules and Procedures. Specific training in facility operating rules and procedures are detailed in the HFEF Operation and Maintenance Manual.
- On an annual basis staff members are given refresher lectures on the principles and practices of radiation safety. New staff members are given individual instruction if they are not familiar with standard radiation safety procedures. These lectures are prepared and presented by staff personnel from Radiation Safety.

D. Staffing and Organization of HFEF

The HFEF complex consists of two facilities, HFEF/S and HFEF/N, which have a common management and support structure with separate but interchangeable operating crews. This organization is illustrated on Fig. II-2. The HFEF-complex manager is responsible to the site manager, ANL-W, who, in turn, reports to the Laboratory Director.

The duties and responsibilities of the positions shown on this organization chart are given below. Detailed interfaces are described in the HFEF Management Plan.

- HFEF-Complex Manager--Overall responsibility for all activities conducted within the organization. These include, but are not limited to budget preparation and management, planning and scheduling, safety, personnel, interface with other organizations, facility operation, policy, and comppliance with applicable regulations.

To assist the HFEF-complex manager, responsibility for some of these duties has been delegated to the four section managers as follows:

- Operations Support Manager--responsible for assuring compliance with all safety considerations of operations; for preparation, approval, and issuance of the Operation and Maintenance Manual and other procedures; for coordinating facility reports; for training; for fuel management; and for review of operations conducted by the organization to assure that they are performed in a safe, efficient manner. He is assisted in these duties by staff members who are assigned to his section.
- Operations Manager--responsible for the scheduling and conduct of examinations carried out in the facilities; for the installation, operation and maintenance of in-cell and out-of-cell equipment required for operation of the shielded cells; for assignment of operating personnel; and for assuring that all operations are conducted in a safe, approved manner. He is assisted in these duties by the two facility supervisors and other staff, monthly, and weekly personnel assigned to his section.
- Experimental Coordination Manager--responsible for coordinating the efforts of the HFEF complex that involve obtaining data from irradiated fuel and structural materials. Included in this function is the liaison between HFEF and the experimenters and between HFEF and the irradiation facilities. He is also responsible for coordinating the experimental requirements with the facility capability and providing criteria for new equipment. In these functions he interfaces directly with the Operations Section, the Operations Support Section, and the Operations Engineering Section.

Fig. II-2. Organization Chart for the HFEF

- Operations Engineering Manager--responsible for the design and procurement of the equipment that is used for the postirradiation examinations within HFEF and for assuring that all new equipment meets the design criteria. Further, he is responsible for assuring that new equipment needed for future examinations is available and operationally proven at the time the experimental examination is scheduled. He maintains fiscal accountability for the design and procurement of new equipment and represents the HFEF in interfacing with other design efforts such as building changes and construction work.
- Facility Supervisors--one for HFEF/S and one for HFEF/N, report to the Operations Manager. They are responsible for implementing the directives of the Operations Manager in their respective facilities.
- Engineering Staff--report to the Operations Engineering Manager and are responsible for supervision and implementation of the design and procurement efforts carried out by the Operations Engineering Section.
- Zone Engineers--Each zone within the shielded cells is assigned to the direct supervision of a zone engineer. He has the responsibility, and commensurate authority to maintain control of all activities conducted within his zone. He is responsible for assuring that approved procedures are followed, that operations are conducted in a safe and efficient manner, and that the zone and the equipment in it are operated and maintained in the optimum condition. Each directs the efforts of the chief technicians and technicians working in his zones and reports to the respective facility supervisors.
- Systems Engineers--have the same responsibilities and duties as the zone engineers, except that they apply to a system (e.g., argon cell atmosphere) rather than a work zone. They report to the operations manager.
- Cognizant Engineers--report to the manager of experimental coordination. Each experiment handled within the HFEF is assigned to a cognizant engineer. He is responsible for obtaining the examination requirement from the experimenter and for transmitting these requirements to the appropriate HFEF personnel. He follows the experimental examination to ensure that the requirements are met and in some cases represents the experimenter during the examination. He transmits the results of the examination to the experimenters.
- Chief Technicians--responsible for the direct supervision of technicians working either in a zone or on a system.

SECTION III
SAFETY EVALUATIONS

III. SAFETY EVALUATIONS

A. Criticality Hazards Control

The controlling documents for the nuclear criticality safety of HFEF/N are the Criticality Hazard Control Statements, CHCS, the review and approval of which constitute the nuclear safety evaluation of the facility. These documents will reflect the as-built and operated status of HFEF/N in areas affecting nuclear criticality safety. The following description and discussion is presented for information only and is not to be considered a controlling statement. These are typical of the considerations in the examination of the nuclear criticality safety of the facility.

1. General Bases

Unlike the situation in chemical processing plants, many of the operations in HFEF/N are not adapted to geometric control to ensure criticality safety. Criticality control is therefore based primarily on division of the operating areas into zones and subzones with administratively controlled limits for fissile material permitted in each zone.

The layout of the zones is necessarily based on projected operating patterns, but administrative control requirements are also considered. For example; in the shielded cells, the zone associated with each window must be within the unobstructed view of the individual responsible for operations at the work station. Although the requirement is not so severe in the out-of-cell area, the same principle holds: each zone must be clearly within the surveillance of the individual in charge at that area.

The maintenance of an accurate running inventory at each work area where fissile material is handled is essential to criticality control by zones. The use of a tag board system will provide an adequate margin of safety. These boards are prepared in advance to represent the arrangement of zones in a working area, and tags are placed on hooks attached to the board to represent each item of fuel (or moderator, where moderators are restricted) moved into the area. Totals are checked before each move to make sure that no posted zone limit is exceeded. Written records are also kept, and these are reconciled with the tag board inventories at frequent intervals (at least weekly). Written documentation is not required for fuel transfers between zones in the same criticality control area, but is required for transfers between cells or between separate buildings.

Zones are classified according to the amount of moderator permitted in the area as moderator-unlimited, moderator-limited, or in a few cases, effectively moderator-free. The limits of allowed fissile material in the zones are then adapted from standards such as the Nuclear Safety Guide, TID-7016, for the particular physical form of the fissile materials involved.

These standards have been supplemented by extensive calculations for individual cases that do not meet the usual criteria. The KENO Monte Carlo code with the Hansen and Roach cross-section set has been a particularly useful calculation tool for verifying the subcriticality of numerous storage arrangements and interaction effects involving fissile masses.

Transfers of fissile masses throughout the HFEF/N facility are programmed to follow paths that are well separated from the working areas. Transfers of fuel within the shielded cells must be accomplished with remote handling equipment. In these cases restricting fuel transfers such that fuel is not permitted to be carried closer than one foot to existing fuel masses in the working area will provide an adequate margin of safety. A cart for transferring materials from zone to zone along the periphery of the Main Cell is separated by exclusion zones from the fissile materials in the working zones.

Much of the equipment and procedures utilized in the initial operation of the HFEF/N facility has already been analyzed and proved by experience in the HFEF/S. This includes birdcages and casks, the analyses for which are similar to those contained in documents approved previously.

The precautions against accidental criticality invoke the double contingency philosophy; that is, at least two independent situations, either of which has an extremely remote probability, must occur simultaneously in order to cause an accidental criticality. The contingencies may consist of the failure of administrative controls as well as physical assurances of safety.

A formal criticality training and qualification program is established for personnel handling fissile material in the facility. The program is stated in the Argonne-West General Plan for Nuclear Criticality Safety, ID-CHCS-G01.

2. Out-of-cell Areas (Criticality Hazards Control Statement ID-CHCS-A102)

The out-of-cell areas are grouped into the following four major zones:

- Metallography Laboratories. Two rooms (Room 125 and Room 123; see Fig. III-1) constitute the metallography laboratories. Room 125 provides capabilities for metallographic examination of nonirradiated (or very low radiation level) fuels and structural materials. Commercially available metallographic equipment is provided. Liquid wastes from this room drain to the building's suspect waste systems. This room is considered to be one criticality subzone and is separated from Room 123 (metallograph room) by a 6-in.-thick (nominal) concrete block wall which contains a door for personnel use between the two rooms.

Fig. III-1. Criticality Subzones in the Metallography Laboratories and Radiation Monitoring on Operating Floor. ANL Neg. No. 103-12471 Rev. 2.

Room 123 is used for preparing irradiated samples (fuels and structural) for examination in the metallograph and in the scanning electron microscope. The shielded loading cell (see Fig. III-1) represents one subzone and the remainder of the room another. The lead (8 in.) and steel (15 in.) shielding of the loading cell is adequate to separate it nuclearly from the rest of the room.

- Physical Test Laboratory (Room 204). This room (see Fig. III-2), constituting one separate criticality zone, may be used to subject non-irradiated (or very low radiation level) specimens, both fuel and structural, to various mechanical tests and physical property measurements.
- Retention Tank Room (Service Floor). (See Fig. III-3.) Two 1500-gal tanks are located here for separately collecting liquid wastes from: (1) Decon Cell operations, and water (potentially from building internal sources) draining from the transfer tunnel to sumps in the Decon Cell and tunnel; and (2) building suspect waste system. A floor drain in this room leads to a room sump which discharges to the Decon Drain Tank. Tanks after filling are sampled and analyzed for fissile content. They are pumped out to the Laboratory and Office Building for treatment only with the prior written approval of the Manager, Analytical Laboratory, ANL-West, or his designated alternate.
- General Building Zone. This zone comprises all other out-of-cell areas in the building except (1) those areas identified as separate zones above; and, (2) the Main Cell and Decon Cell areas covered by separate criticality hazards control statements (see below).

Within the out-of-cell areas, all zone and subzone boundaries are clearly defined by painted or taped stripes or by a physical wall. Where zones include floor areas the stripes are painted or taped on the floor and where tables constitute a zone stripes are painted or taped on the edge of the tables. Storage of fissile material is in birdcages which provide an 8-in. controlled open space in all directions. Mass limits of fissile material and of moderator material have been established for each control zone and for each storage operation. Signs are posted to identify the location of criticality control zones and to summarize the criticality control rules for fissile limits for the zones.

All four major zones in the out-of-cell areas are specified as moderator-unlimited. The allowed limits for isolated units in these zones, when not contained in sealed containers, are listed in Table III.1.

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NOTE: The High-Level Gamma Monitor (criticality monitor) will be present when fuel is present in Room 204.

Fig. III-2. Criticality Zone in the Physical Test Laboratory and Radiation Monitoring on Second Floor. ANL Neg. No. 103-12990 Rev. 3.

Fig. III-3. Criticality Zone in the Retention Tank Room and Radiation Monitoring on Basement Floor. ANL Neg. No. 103-12989 Rev. 3.

TABLE III.1. Limits for Moderator-unlimited Zones
(safety factor 2.3)

Material Form	Fissile Material Limit (kg)		
	^{235}U	Pu	^{233}U
Solutions or dispersions of particles, moderated	0.35	0.22	0.25
Loose or hand-carried capsules and elements	0.35	0.22	0.25
Elements in a subassembly, magazine, or single capsules			
Flooded H/X atom ratio			
$\text{H/X} \leq 2$ (includes EBR-II drivers)	9.0	2.4	2.8
$2 \leq \text{H/X} \leq 20$	3.0	2.2	1.3

Nuclear analyses of the various operations and systems of the out-of-cell areas have been performed and found to present no criticality hazards as shown below.

a. Ventilating-air Filtration System

It is conceivable that specific locations in the ventilation ductwork may be prone to collect dust and that local accumulations of fissile dust will occur. Any such collection of fissile dust will be conspicuously radioactive because of the predominance of irradiated over nonirradiated fuel in the long-range program of fuel handling. It has been the experience in the HFEF/S program so far that even gram quantities of irradiated fuel outside the cell are so radioactive that they are easily detected in the normal course of radiation monitoring and are not allowed to accumulate. The normal housekeeping and disposal procedures for these small quantities will prevent any buildup to the size which could be regarded as a criticality hazard.

b. Liquid Waste System

There are two 1500-gal suspect waste tanks on the service floor level. One is made of stainless steel and in normal operations receives the drainage from the Decon Cell. The other, a plastic lined tank, normally receives drainage from the laboratory sinks and drains throughout the HFEF/N building. Valving arrangements permit the laboratory drains to flow into the stainless steel tank. Inasmuch as the tanks will be operated at any level from full to empty, any fissile sludge or solution collected in either tank must not exceed the amount that is safe in any concentration. Since the 350-g limit applies to each tank, circulation and interchanges of fluids between them is not permitted unless an analysis has shown that the sum of fissile material in both tanks is less than 350 g ^{235}U or the equivalent. As soon as one of the tanks is full, the contents will be agitated and analyzed before it is pumped to the Laboratory and Office Building tank for ultimate disposal.

Radiation sensors in the suspect waste tank area will continuously be monitored in the control room and will be equipped with alarms for high levels of radiation.

Control of fissile materials in the tanks will be by analysis and by limitations on the inputs. It is concluded that the process and administrative controls are such that a hazardous accumulation of fissile waste in the suspect waste tanks is not credible.

c. Metallography Laboratory

Criticality control in the metallography laboratory will be by inventory rather than by geometry or capacity limitations. This is regarded as a moderator-unlimited area, so that fissile materials in each CHC zone will be limited to 350 g ^{235}U or equivalent, a quantity that is safe in any admixture with hydrogenous materials.

All movements of fuel into and out of the metallographic laboratory will be inventoried in a record book (log). Movements of fuel between work zones, and the contents of each zone will be kept up to date on tag boards.

Fuel materials in the metallographic laboratory fall into four categories: pins, scrap, mounted samples, and cutting and grinding wastes. Pins and scrap will be permitted up to the limit of 350 g ^{235}U per zone. Mounted samples and weighed accountable scrap will be stored in approved safe geometry. Grinding and polishing wastes will be collected batchwise as produced and disposed of as dry active waste. Saw wastes will be counted and included in the 350-g zone limit as follows: saw cut wastes ("sawdust") will be collected with water in a tank below the saw. The saw kerf is less than 0.1 in. wide, which represents about 0.5 g of fissile material each time a typical EBR-II fuel pin is sectioned. A log will be maintained, recording each cut of fissile material. Every time 100 fissile sections are completed, or about 50 g fissile "dust" produced, the saw tank will be cleaned of all sludge. The sludge is transferred to SPM for disposal or recovery.

The metallography laboratory is regarded as one CHC zone divided into three subzones. One subzone comprises the shielded loading cell in the metallograph room, Room 123. The second is the balance of the metallograph room separated from the interior of the loading cell by at least 8 in. of shielding which serves as an 8-in. exclusion zone. The third subzone in this area is the metallographic laboratory room, Room 125, containing cutting, grinding, and polishing equipment and operations. This is separated from the metallograph room by an 8-in. wall which serves as an exclusion zone. Cutting and grinding operations are performed in a small anteroom which is part of this third work zone.

Each of the above three work zones has a limit of 350 g ^{235}U or equivalent out of a birdcage. Exposed plutonium or ^{233}U may be permitted in the loading cell subzone but not in the other two subzones. Sealed storage containers or capsules of plutonium or ^{233}U may be permitted in the other subzones of the metallography laboratory, within the authorized limits, but not in the sawing/grinding anteroom. Several birdcages are permitted in Rooms 125 and 123, and their contents, within the limits established in Table III.2, are allowed in addition to the above 350 g or equivalent.

TABLE III.2. Fissile Material Limits for Birdcages

Small Birdcages (maximum $\text{H}/^{235}\text{U}$ atom ratio, 2): 4.62 cu ft, 48 units allowed in array (TID-7016 Fig. 22).

- (a) 16 kg ^{235}U or its alloys (^{235}U only) as ingots; or
- (b) 6 kg ^{235}U as feedstock (derbies, etc.) or
- (c) 1 kg ^{235}U or its alloys (^{235}U only) as fines.

Modified Cold-line Birdcages (used only for storage of ^{235}U and contains $4\frac{3}{4}$ -in. I.D. insert and is so tagged): 14.7 cu ft, 110 units allowed in array (KENO calculations).

- (a) 16 kg ^{235}U with a maximum $\text{H}/^{235}\text{U}$ atom ratio of 2; or
- (b) 7 kg ^{235}U with 2 kg PVC (H max, 7 wt %) with a maximum $\text{H}/^{235}\text{U}$ atom ratio of 4.7 or with 1 kg polyethylene (H max, 14.4 wt %) with a maximum $\text{H}/^{235}\text{U}$ atom ratio of 4.8; or
- (c) 3.6 kg ^{235}U with a maximum $\text{H}/^{235}\text{U}$ atom ratio of 20.

Experimental Capsule Birdcages (6.5 cu ft, 65 units allowed in array; or 9.31 cu ft, 83 units allowed in array).

3.6 kg ^{235}U or 2.4 kg Pu or 2.0 kg ^{233}U (mixtures limited to the most restrictive masses) with a maximum H/X atom ratio of 20.

All of the above birdcages, when containing plastic-mounted metallographic samples, are limited to 350 g ^{235}U and are restricted to use in the metallographic laboratory zone, except as authorized in a transfer document.

Additional subzones may be set up in the metallography laboratory as needed upon written approval of the HFEF/N Manager or his designated alternate, subject to the restriction that each subzone be at least three feet in its minimum dimension and be surrounded by an 8-inch exclusion zone.

As previously noted, wastes from the saw operation will be accumulated not to exceed 50 g in the saw container. The container will then be cleaned of all sludge. This conservative limit will allow sufficient margin so that there is no possibility of an accidental criticality, even if the estimate of saw kerf should be in error by a factor of 16. Wastes from the saw container must be transferred out of the metallograph laboratory to SPM before the saw is used again.

Fissile wastes from the grinder are smaller by an order of magnitude than those from the saw, and wastes from the polishing operation smaller again by another order of magnitude. Fissile waste from these two operations are collected in small batches sorbed on Oil-dri and disposed of as dry active waste.

d. Physical Test Laboratory

Moderators are not limited in this laboratory. The fissile limit for the entire physical test laboratory is 350 g ^{235}U , or 250 g ^{233}U , or 220 g plutonium, all of which are safe in a moderator-unlimited zone. The entire lab consists of a single zone.

Unirradiated fuel will be handled in the physical test laboratory. At present there are no facilities here for handling bare plutonium.

e. General Building Zone

The general building zone is a moderator-unlimited CHC zone.

Up to 20 approved birdcages (minimum lattice volume 4.6 ft³) or coffins may be located in this zone. They must be closed watertight when not attended. In addition, the following quantities of fissile materials shall be permitted out of birdcages or coffins:

- One subassembly or magazine, which must be kept at least 8 in. from other fissile material and may not be left unattended; the fuel content must fall within the limits of Table III.1 for the appropriate H/X atom ratio, and
- 350 g ^{235}U , or 250 g ^{233}U , or 220 g Pu (mixtures of these are limited to the most restrictive masses) separated by at least 8 in. from other fuel, or
- In lieu of the masses listed in the above item, two approved experimental capsules, maintained at least 8 in. from other fuel.

The above birdcage arrays at 4.6 ft³ per lattice unit would be safe up to 48 units according to TID-7016, Fig. 22.* All approved coffins have sufficient shielding to assure at least a comparable spacing, eight inches surface-to-surface. The interactions between a single subassembly and the other out-of-birdcage masses have been analyzed with respect to their fractional subtended solid angles. The worst case would be the interaction of the subassembly with two moderated spherical masses

*This reference does not apply to the modified cold-line birdcages with H/X ratios of 4.7 or 4.8. However, supplementary analyses using the KENO code have shown these to be safe also.

at 8-in. separation. The fractional solid angles are 2.4% each, as shown later in Fig. III-8. The k_{eff} of the individual units is not over 0.73. Accordingly, the interactions are acceptable inasmuch as Fig. 26 of TID-7016 indicates that at these k_{eff} values, solid angles up to 15% are safe.

3. Decon Cell (Criticality Hazards Control Statement ID-CHCS-A103)

The Decon Cell areas include the Decon Cell, the cask tunnel and the shielded transfer tunnel (see Fig. I-2). The following operations are performed in the Decon Cell: (1) decontamination of equipment, irradiated components and loop hardware; (2) clean transfer and packaging of irradiated specimens for offsite shipment; (3) packaging of radioactive wastes; and, (4) transfer of equipment between the Main Cell and the repair rooms above the Decon Cell. All six work stations in the Decon Cell are being initially activated. Materials are handled by means of master-slave manipulators, an electromechanical manipulator, and a 5-ton crane. Storage pits are available for storing subassemblies and other irradiated materials. The cell atmosphere is once-through air. Decontaminating liquids are drained or pumped to the sump in the transfer tunnel.

Fissile material can be introduced into the Decon Cell in various forms such as subassemblies, elements, capsules in magazines or in loops. Bare fuel or fuel with defective cladding will not be intentionally brought into the spray chamber. All fissile materials are received and/or removed from HFEF/N in approved birdcages or approved coffins, except quantities less than 50 g, which may be carried by hand.

Fissile materials are administratively controlled by means of zone limits and running inventories. A central inventory log is maintained to indicate the total amount of fissile material present in the Decon Cell. Regularly scheduled monthly inventories are made to verify the quantity and location of fissile material. The loop decontamination pit, the spray chamber, and the storage pits have been established as moderator-unlimited zones. The rest of the Decon Cell, including the hatches to the cask and transfer tunnels and the wall transfer lock, are moderator-limited zones (500 ml hydrogenous fluid max). The fuel limits for these zones are given in Tables III.3 and III.4.

During initial operation of the Decon Cell the fissile material limits for restricted-moderator zones will not be used except when the water supply to the spray chamber is sealed shut. Only after operating experience has shown that the water in the spray chamber can be reliably isolated from the other cell areas will the larger fissile limits be permitted simultaneously with spray operations.

TABLE III.3. Limits for Decon Cell Moderator-unlimited Zones
(spray chamber, storage pits, and loop pit) for
Material Out of Casks or Birdcages

Material Form	Fissile Material Limit (kg)		
	²³⁵ U	Pu	²³³ U
Particles or solutions	0.35	0.22	0.25
Loose capsules	0.35	0.22	0.25
Single capsules, or elements in a fixed geometry, as in a subassembly or magazine			
Flooded H/X atom ratio			
H/X ≤ 2 (includes EBR-II drivers)	9.0	2.4	2.8
2 ≤ H/X ≤ 20	3.0	2.2	1.3

TABLE III.4. Limits for Decon Cell Moderator-limited Zones
for Material Out of Casks or Birdcages

Moderator Limit	Fissile Material Limit (kg)		
	²³⁵ U	Pu	²³³ U
Hydrogenous liquids, 500 cc (max)	10.0	2.5	2.5

The criticality control zones are related to the viewing windows approximately as shown in Fig. III-4. The spray chamber associated with window 6D is a moderator-unlimited zone. The loop decontamination pit constitutes a moderator-unlimited zone of the window 5D area. The three storage pits are taken together to form a moderator-unlimited zone at window 3D. The clean area, window 1D, is a moderator-limited zone. The setdown area west and south of the hatch to the transfer tunnel is part of the moderator-limited zone associated with window station 3D. The remaining floor area is a moderator-limited zone associated with window 2D.

No fuel is expected to be raised up to the hot repair room or suspect repair room above the Decon Cell. However, these rooms may be used for the transfer of fuel into the Decon Cell from above.

Nuclear analyses of the various areas and operations have been performed and found to present no criticality hazard as shown below.

a. Flooding

The transfer tunnel and cask tunnel are located below grade, and as a result, there is an extremely remote possibility of their flooding. The floor drains in the transfer tunnel lead to a sump at the low point in the transfer tunnel. Drains in the cask tunnel area have been capped.

Fig. III-4. Criticality Zones in Decon Cell. Exclusion zones are designated by diagonal-line shading. ANL Neg. No. 103-12455 Rev. 2.

There is a water level alarm on the sump to indicate any time that it is becoming too full so that early warning of any flood condition would be given. From the sump, water is pumped out to the suspect waste tank.

Should the tunnel sump pump fail to cope with a flood situation, water would leak from the tunnels into the entire basement where it would run to a second sump and be pumped into the suspect waste tank. If both sump pumps should fail to alleviate the condition, water would flood throughout the service floor, but it is not credible that it would rise to a level where it could enter the top of the transfer vessel, 11 ft above the floor, as this would require over a million gallons. The same argument applies to the cask tunnel; however, all approved casks are safe even when flooded.

Under the above conditions, therefore, fuel in the cask tunnel and transfer tunnel might be externally reflected by flooding waters but could not be internally flooded. The zone limits of Table III.4, for moderator-limited areas, are therefore applicable in these tunnels.

b. Fuel Limits in Moderator-unlimited Areas

Fuel will be present in the Decon Cell as subassemblies, magazines, elements, capsules, or loops. Bare fuel or fuel with known defective encapsulation will not be introduced intentionally into the spray chamber of the Decon Cell.

(1) Subassemblies. It is unlikely that fully fueled subassemblies will be handled in the Decon Cell, because of the cooling problems. However, the possibility exists that reassembled subassemblies (partially irradiated) will be handled, or other circumstances may require a provision for handling subassemblies. In this case, limits will be set up as in Table III.3, depending on the open area and consequent H/X atom ratio achievable in the flooded condition. For example, for an EBR-II driver subassembly, the H/X atom ratio is 1.92, based on the open area of the subassembly, and assuming fully enriched fuel. In this case, 9 kg of ^{235}U would constitute a safe isolated batch (safety factor 2.3).

Subassemblies of other than EBR-II designs may have higher potential (when flooded) H/X ratios, and consequently the safe isolated batch is reduced to 3 kg ^{235}U or 2.2 kg plutonium or 1.3 kg ^{233}U ($2 < \text{H/X} \leq 20$).

Although the sizes of these limits are adjusted for safe isolated units, they are also safe for small arrays. Thus, the normal spacing of units in their individual zones is sufficient so that no unsafe array can accumulate. The minimum dimension in each zone is at least three feet. The spacing between zones is an 8-in. wide exclusion band and at no place do more than four zones come together. The 8-in. exclusion distance plus the radii of the subassemblies provides sufficient separation for an array of four units to be safe.

(2) Magazines. Magazines, or devices for holding elements in a fixed, roughly parallel geometry, will be used to transport groups of elements in the Decon Cell, including locations in the spray chamber. No magazine will be used in the moderator-unlimited areas unless it either satisfies the criteria for subassemblies in regard to flooded H/X ratio and fissile material content, or is approved on the basis of other analyses.

(3) Storage Pits. There are three storage pits in the zone opposite window 3D, about 24 in. center-to-center. They are not cooled and consequently not suitable for containing large masses of irradiated fuel. From the criticality point of view, subassemblies containing up to 9 kg would be safe in the storage pits, since the fractional subtended solid angle between two 2.3 x 21 in. subassemblies spaced 23 in. center-to-edge is 0.75% (1.5% from the central subassembly to the other two) providing adequate isolation for units that are far subcritical in themselves.

Groups of capsules or elements that are not rigidly positioned and centered will not be placed in the storage pits. Single capsules would be safe up to the limits given in Table III.3 because the interaction would be no greater than for full subassemblies. Moderated masses up to 0.35 kg ^{235}U are safe at separation distances of 8 in. and are therefore safe in the storage pits.

To avoid an accidental dropping of extra fissile material into a pit, the pit will be covered except when fuel loading or unloading operations are underway.

Thus, any of the units which lie within the limits of Table III.3 and which are allowed in the individual storage pits are safe in any array in the storage pits. To avoid thermal damage, no capsule or subassembly will be stored in the storage pits under conditions which are calculated to raise its surface temperature above 800°F under natural convection.

(4) Storage-pit Array. An array of three storage pits has been analyzed in a series of KENO calculations. In each calculation, the pit, represented as a 16-in. diameter cylinder in a 2-ft square box of concrete, was loaded with a central cylinder representing a 9-kg ^{235}U subassembly, 2.32 in. in diameter by 16.87 in. high. The normal, unflooded array of three such storage pits had k_{eff} of 0.42 ± 0.02 . When flooded, k_{eff} was 0.67 ± 0.03 . To further determine the effect of the concrete on the interactions of the storage pits, all concrete was removed from around them. This produced a k_{eff} (unflooded) of 0.36 ± 0.03 . These calculations indicate that interactions among the storage pits, though enhanced by concrete and by flooding, are not sufficient to entail a criticality hazard.

(5) Waste Containers. Dry fuel wastes are handled in closed steel containers. Provision is made for transfer of these containers out of

the Decon Cell through the clean room. The fissile material is limited to 500 g ^{235}U or 300 g Pu or ^{233}U in any container. These limits provide a safety factor of 1.7, which is in line with those proposed in TID-7016 for storage arrays. The closed containers are not opened after they are transferred out of the Decon Cell, except in a criticality-controlled area.

(6) Loop Decon Pit. A 30-ft deep pit approximately 33-inches in diameter is located at window station 5D. Complete loops may be immersed in this pit and washed by ultrasonic or other methods. The pit will be kept covered except when loading or unloading operations are underway.

The geometry of the loops is not specified yet, but it will be required that they meet the criteria of safety when flooded. In addition, no device in which there is exposed fuel (exposed to the Decon Cell atmosphere), or for which there is reason to suspect that any failure which might expose fuel has occurred, will be washed in this tank.

(7) Fuel Transfers. Transfer of fuel through the Decon Cell will be accomplished by master-slave or E-M manipulators or by crane. Units of fissile materials will not be brought closer than 1 ft to other fissile masses during transfers. This will ensure more clearance and safety than the normal 8-in. zone boundaries. Not more than the zone limits established in Table III.3 will be transferred at any one time. Transfers of fissile material across zone boundaries will be recorded on tag boards as they occur to assure proper zone inventory control. Transfers into or out of the Decon Cell will be recorded in a log and SPM documentation will be accomplished.

(8) Drain Sumps. The drain sump at the low point of the transfer tunnel receives drainage from the Decon Cell floor, demister drain and the storage pits. No exposed fuel is to be washed in any of the above areas. If by error a defective fuel capsule or element should inadvertently be exposed to liquid in one of these areas, the defect combined with the quantity of liquid would have to be such as to permit the passage of 0.82 kg ^{235}U , or the equivalent, before criticality in the sump could occur, and such a large transfer of fuel is regarded as improbable. It is therefore not considered possible that the sump could accumulate a critical mass of fissile material. Liquids from the Decon Cell spray chamber drain into a separate sump in the floor of the Decon Cell, through filters to the Decon Drain Tank in the retention tank room.

(9) Ultrasonic Cleaner. An ultrasonic cleaner in the Decon Cell will be used principally for cleaning hardware. Since this cleaner involves immersion in hydrogenous liquids, fuel capsules can be cleaned only under restrictive conditions that less than 0.35 kg ^{235}U (or equivalent) is in the bath of the cleaner. The ultrasonic cleaner may be installed in the loop decon pit or other cleaning vessel.

c. Fuel Limits in Moderator-limited Areas

The moderator-limited nonfloodable areas associated with the Decon Cell are the clean room, the transfer hatch and setdown areas, and work stations 2D and 3D. In addition, with fuel in casks, the cask tunnel and transfer tunnel may be regarded as moderator-limited zones, although these areas have only a remote chance of being flooded, as discussed above. Up to 500 cc of hydrogenous liquids are normally permitted in any of these zones. This amount of moderator mixed with the limited quantities of fuel listed in Table III.4 leads to H/X atom ratios of 1.3 for ^{235}U and 5.2 for plutonium or ^{233}U . The amounts of fissile materials listed in Table III.4 are safe at these H/X atom ratios.

(1) Transfer Hatch and Tunnel. No fuel is to be stored over the transfer hatch. The transfer hatch and tunnel are regarded as a zone in which fuel and moderator, up to the limits of Table III.4, may be transported. The transfer hatch will be kept closed when material is not being moved through it. The transfer hatch is protected by a lip so that water spilled on the floor of the Decon Cell will not run down through the hatch opening unless the water is over three inches deep on the Decon Cell floor. If water on the Decon Cell floor should ever become this deep, the hatch lip would provide an overflow to drain the water into the transfer tunnel. This would consume sufficient time so that the transfer vessel could either be unloaded or moved to a position where water would not drain into it. While the transfer vessel contains fuel, it may not be left unattended under the transfer hatch of the Decon Cell.

(2) Cask Tunnel. All casks for use in the cask tunnel will be on the list of approved casks. These are all safe when flooded as long as their fuel content does not exceed the limits set in ID-CHCS-A102.

d. Interactions between Limits in Adjacent Zones

The subject of interactions has been discussed for the special cases of subassemblies in Section b(1), and for the storage pits in Section b(4). Both of these interaction conditions were found to be safe.

In addition, however, it is necessary to examine the general situation for all the zones containing fuel and moderator materials up to their allowed limits. All the zone limits listed in Tables III.3 and III.4 constitute less than 43% of a critical mass, and therefore their individual k_{eff} is of the order of 0.75 in their most reactive spherical configuration. At this k_{eff} , fractional subtended solid angles up to 11% between units are safe. Across an 8-in. zone boundary the largest fractional subtended solid angles between the most reactive masses are 3.5%. Interactions of allowed masses across zone boundaries are therefore safe.

e. Administrative Controls

Administrative controls are required to keep the fuel inventory in each zone within the limits allowed in Table III.3 or III.4. Tag boards for each zone will be kept up to date reflecting each fuel transfer in and out of the zone. In addition, fuel transfers to or from areas outside the Decon Cell will be recorded in a logbook for this purpose and the transfer documents required by SPM will be completed. With these controls, compliance with the zone inventory limitations is assured.

During fuel transfers between different zones within the Decon Cell, a minimum of 1 ft surface-to-surface spacing is to be maintained between the transferred fuel and any stationary fuel units. This requirement is to be controlled administratively. Compliance is assured by adequate training of operators and by frequent operational spot-checks by supervisors.

4. Main Cell (Criticality Hazards Control Statement ID-CHCS-A104)

a. Operations

The Main Cell is utilized for destructive and nondestructive examination of irradiated fuel and structural materials. Fifteen work stations are provided. Materials are handled by means of master-slave manipulators, electromechanical manipulators, and 2 cranes. A remotely operated interstation cart is also used for in-cell transport of materials between stations. Storage pits are available for storing subassemblies and other irradiated materials. A storage and transfer zone is also provided. The cell contains argon, which is recirculated and purified, to provide an inert atmosphere. Containment boxes (initially one) are provided for in-cell metallographic operations, which require fluids which might be harmful to the argon purification system. Liquids are limited to batch quantities which are piped directly to this box, which is well isolated from the rest of the cell. Liquids are drained from the containment box(es) to a Raschig ring poisoned tank located in the cask tunnel. The contents of this tank are circulated and sampled prior to disposal. There are no other plumbing connections directly tied in with the cell. Material may be transferred in or out of the Main Cell through the various penetrations shown in Fig. I-10.

Fissile materials are administratively controlled by means of zone limits on fissile mass and running inventories thereof. A central inventory log is maintained to indicate the total amount of fissile material present in the Main Cell. Regularly scheduled inventories are made to verify the quantity and location of fissile material.

The principal operations and measurements to be performed in the Main Cell are listed below. This list is, of necessity, incomplete. However, future operations and measurements not described at this time will not be introduced into the Main Cell operations without further approval if they do not conform to the fissile and moderator restrictions in the approved Criticality Hazards Control Statement ID-CHCS-A104.

Fuel and material specimens irradiated in EBR-II and other test facilities will be subjected to certain nondestructive or interim examinations during their irradiation lifetimes. At the completion of irradiation, the specimens will receive a terminal examination (not necessarily destructive). Aside from the handling problems, examinations and operations on the individual loop specimens will be the same as those normally performed on EBR-II capsules or elements.

The nondestructive examinations include the following:

- Visual and photographic inspection
- Dimensional and weight measurements
- Neutron radiography (future)
- Gamma scanning
- Leak testing
- Sodium-bond testing and sodium-level determination

The destructive examinations include the following:

- Sampling for chemical analysis
- Sample preparation for metallographic examination in the containment box, including cutting and sampling, mounting, coarse and fine grinding and polishing and etching.
- Density determination
- Fission-gas sampling

In-cell equipment is being furnished to do the following mechanical operations:

- Subassembly assembly and disassembly (vertical assembler dismantler-VAD)
- General machining and welding
- SLSF handling, assembly and disassembly

Operations not fitting under above-mentioned classifications include the following:

- Waste or sample packaging
- Subassembly (including hardware components) and sample storage
- Equipment storage

- Fissile and structural material transfers (as EBR-II sub-assemblies, capsules, elements, etc.) between the Main Cell and the following: (1) the Decon Cell and out-of-cell areas in HFEF/N, (2) other ANL-West criticality hazards control zones or other organizations at the INEL, Idaho, in approved containers; and (3) organizations not located at INEL, Idaho, in DOT-approved containers.
- Pneumatic transfers of irradiated fissile and structural materials between the following areas: (1) the containment box, station 2M, Main Cell and the shielded loading cell, metallograph room (Room 123); and (2) the shielded loading cell, metallograph room (Room 123); and window 15M, Main Cell.
- Transferring structural materials, equipment and components through the roof hatch to the repair areas above the Main and Decon Cells.

b. Nuclear Analysis

Nuclear analyses of the various operations and areas have been performed and found to present no criticality hazards as shown below.

The Main Cell is characterized by an inert argon atmosphere, no plumbing (except in containment boxes well isolated from the rest of the cell), fifteen criticality zones associated with the window areas, as well as other zones for storage and transfers.

Each window will have associated with it a 10-ft wide x 8-ft deep criticality hazard control zone, unless the dimensions are specifically set otherwise because of the nature of the operations involved. Provisional layout of the criticality control zones is shown in Fig. III-5.

Each 10 x 8-ft zone is moderator-limited. A maximum of 500 cc of aqueous or organic liquids is permitted in each of these zones. Under these restrictions, the limit in each zone is set at 10 kg of ^{235}U fuel or equivalent. This (or any smaller) amount of fuel is safe, as shown below.

Depending on the nature of the solvent, the H/X atom ratio for 500 cc of solvent mixed with 10 kg of ^{235}U is 1.16 (for methyl alcohol), 1.30 for amyl alcohol, to 1.31 (for water). A mass of ten kilograms of ^{235}U is safe at the above H/X atom ratios (TID-7016, Fig. 1). Reduction in the amount of fuel increases the H/X atom ratio and, with reference to Fig. 1 of TID-7016, has the effect of describing points on a line to the left of the point at 10 kg, $\text{H/X} = 1.3$, and downward at an angle of 45° . All points on this line are less critical than the safe limit shown in Fig. 1, TID-7016.

The fact that reduction in fuel content of units reduces the criticality even though the H/X atom ratio increases has been further confirmed in KENO calculations.

If the quantity of moderator is reduced without reduction of the 10 kg mass of ^{235}U , the effect is to define points on a line extending horizontally to the right of the 10 kg, H/X = 1.3 point on Fig. 1, TID-7016. All such points are also within the safe limit region. It is concluded that any combination of ^{235}U up to 10 kg and moderator up to 500 cc will constitute a safe isolated mass. Similar reasoning demonstrates the safety of up to 2.5 kg Pu or ^{233}U with up to 500 cc of solvent.

In the VAD zone, one subassembly (limit 10 kg ^{235}U or equivalent) at a time will be permitted.

The 10-kg subassembly limit is safe with the limited amount of moderator (500 cc) permitted in this zone as shown above.

The capacity of the wall transfer locks between the Decon Cell and the Main Cell will be limited according to Table III.5 for moderator-limited areas. This is consistent with the moderator-limited nature of the Decon Cell and with the limits that are in force in the Decon Cell.

TABLE III.5. Limits for Main Cell

	Fissile Material Limit (kg)		
	^{235}U	Pu	^{233}U
<u>Moderator-unlimited Area</u>			
In containment boxes (with cadmium isolation)	0.44	0.44	0.44
<u>Moderator-limited Areas</u> (500 cc hydrogenous liquid per zone)			
Main Cell	10.0	2.5	2.5
Casks and birdcages	Limits as specified in Table III.2		

The analysis above applies to loose pins, solid masses, or small particles (even solutions) of fuel. The 10 kg ^{235}U (or equivalent) limit is therefore safe for loose pins in these zones (safety factor 2.3).

The storage pits in the Main Cell are located 24 in. apart center-to-center. Their inside diameter is 12 in. so that there remains a 12-in. minimum surface-to-surface spacing between contained fuel, of which $11\frac{3}{4}$ in. is concrete, the rest steel. They are protected against overheating and are safe for the storage of subassemblies or waste containers as shown below.

The storage pits are fitted with a position rack and are provided with forced convection argon cooling. The rack and the cooling capacity are designed to accommodate four subassemblies per storage pit. Insertion of the storage rack opens the valve that initiates the flow of argon coolant. Although all pits will be equipped with storage racks, the racks can be removed to permit storage as required. Storage will therefore be limited to four subassemblies per pit, and each subassembly may generate up to 1200 watts of decay heat. The 1200 watts of decay heat is the maximum heat dissipation for which the Interbuilding Coffin (IBC) is designed, with argon cooling at 30 cfm. This amount of cooling has been shown to be sufficient to prevent overheating of irradiated subassemblies both by experience in the IBC and by experiments carried out with electrically heated subassemblies. Because of this experience and because of the backup features built into the cooling system, melting of the subassemblies in storage due to decay heat is not considered credible.

Besides the limit of four subassemblies per storage pit, there is a limit of 18 kg ^{235}U or equivalent per pit, in the form of subassemblies or capsules. With this limitation, and with the one-foot surface-to-surface spacing provided between pits, the contents of the pits fall within the criteria of Table IV, TID-7016, for arrays in which the H/X atom ratio is less than 0.5 for ^{235}U or less than 2.0 for Pu or ^{233}U . Since TID-7016 deals primarily with water-moderated arrays, KENO calculations have been performed to verify that the concrete moderation is safe. These calculations showed that a 5 x 2 array of 12-in. diam pits each containing 18 kg ^{235}U as subassemblies on 24 in. centers separated by concrete has a k_{eff} of 0.50 ± 0.01 .

In any pit which does not contain any subassemblies or capsules, waste cans containing up to 500 g ^{235}U or equivalent per pit may be stored.

The containment boxes (one supplied initially at startup, see Fig. III-6) are used for preparation of metallographic samples of irradiated materials. The quantities of fissile materials are not large, but emphasis here is placed on means for avoiding accumulations of fissile wastes over a long period of time, and on keeping the wastes isolated from usable materials. The safe means for assuring these objectives are described below.

The containment boxes are moderator-unlimited areas, isolated from the rest of the Main Cell. The fuel limits in a containment box are 220 g usable fissile material, plus 220 g waste or scrap. The usable material will be that on which work is being done or completed, and an estimate of the sawdust from the diamond saw. This material will be kept at the level of the tables and working equipment (grinder, polishers) or above. Sumps or filters where filings and grindings will collect are isolated by at least 0.020 in. cadmium sheet from each other and from the working areas. The total accumulation of filings and grindings is kept below a limit of 220 g fissile material by strict inventory control. The inventory control will

require that the fissile content of all major fragments taken out of the box shall be determined by weighing or measuring. To this weight may be added a conservative estimate of the weight of fissile material removed from the box in mounted samples, which cannot be weighed separately because of the plastic mounts. The total in the tag board inventory, including estimates of the weight of mounted samples and diamond sawdust are then added to the output from the box. This sum is then subtracted from the weight of fissile material input to the box. When the difference between these two figures reaches 220 g, all equipment in the box is to be cleaned free of fuel. Sumps will be swabbed and filters replaced. The solid content of sumps will be reduced to essentially zero by cleaning, as determined by visual inspection.

Fig. III-6. Plan of the Main Cell Containment Box. ANL Neg. No. 103-12986.

In this way, no accumulation of waste fissile material greater than 220 g, the safe limit in TID-7016, Table I, is assured. Furthermore, as noted above, the sumps and filters in which this waste material accumulates will be cadmium-isolated from the working material.

Geometric limitations are also used in the containment box to ensure that no individual sump will be critical by itself. The sumps beneath the metallographic sink, high speed saw and grinders are all 3.4 liters or less in volume, which according to TID-7016, Table I, is the recommended safe volume (safety factor 1.3) for solutions of ^{235}U or plutonium. The fluid wastes from the fine polishers, though expected to contain only very small amounts of fissile material, are collected in a tube whose diameter is less than 1.6 inches, which is a critically safe diameter for all solutions of ^{235}U , plutonium or ^{233}U . Other drain plumbing in the containment box is smaller in diameter, and hence, is critically safe. The filters are safe because they will be cleaned (replaced) before 220 g unaccountable accumulates in the box, and because they are cadmium-isolated from the rest of the cell.

A few KENO calculations have been run to determine the effectiveness of 0.020 in. cadmium sheet in isolating the 3.4-liter sumps and filters from each other. First, the k_{eff} of a sphere 18.65 cm in diameter (2.4 liters) containing 220 g ^{239}Pu and the balance water, was calculated to be 0.592. The sphere was calculated as being located in one corner of a 47.7 cm² water-reflected box. Four such spheres in the same box had a k_{eff} of 0.80, indicating that there is considerable interaction between them at this close spacing (5.08 cm surface-to-surface). When a subsequent calculation was made with all four spheres covered with 0.020 in. cadmium, the k_{eff} of the entire assemblage dropped to 0.591, indicating that interaction among the spheres had been entirely eliminated.

Adherence to zone limits will be assured by inventory controls. Tag boards will be used to record all fuel transfers and moderator (solvent) transfers in and out of zones. In addition, any fuel transfers in or out of the Main Cell area (i.e., to or from the Decon Cell, out-of-cell areas of HFEF/N, or other buildings) will require log recording of the transfer, including SPM documentation if required.

When cranes are used for fuel transfers, the amplitude of the swinging of the crane hook will not exceed 1 ft (± 6.0 in.) in any direction. This will be controlled by moving the crane at its lowest speed while carrying fuel, and by stopping as frequently as necessary to prevent swinging. Interactions of fuel units on the crane with other units throughout the cell will be avoided by preventing swinging or adjusting the height of the crane-carried mass as necessary.

The fuel content of the transfer cart will be limited to 10 kg ^{235}U or equivalent, an amount that is safe according to TID-7016, Table I. A sketch of the cart and the adjacent working areas is shown in Fig. III-7. Exclusion zones on the table top and on the floor will prevent the contents of the cart from approaching any closer than 8 in. from the fuel masses in the working zones.

Fig. III-7. Main Cell Interstation Transfer Cart. ANL Neg. No. 103-12987.

The cart may contain long capsules or subassemblies vertically, or short capsules placed at an angle in the upper basket. An exclusion zone marked on the side of the basket at the top will separate these short capsules or fuel sections of long capsules from the fuel masses on the working table. No fuel in the transfer cart will be allowed to project above the lower level of this exclusion zone. Fuel masses on the floor of the working zone will be separated by at least eight inches from the vertical tube of the transfer cart.

To make certain that fissile material carried in the transfer cart will not interact excessively with fissile masses in the 10 x 8-ft working zones or on the working tables, fractional subtended solid angles between the largest masses have been calculated, and the multiplication of the individual masses has been determined by KENO calculations, partially reflected with 24 in. of concrete. The results are illustrated in Fig. III-8 for the two arrangements expected to be most reactive. In either case, the fractional subtended solid angle is less than 3% and the k_{eff} of the individual masses is less than 0.95, so that the interactions are acceptable.

Fig. III-8. Diagram of Interaction between a Subassembly on the Transfer Cart and 10 kg Spherical Masses in the Working Zones. ANL Neg. No. 103-A12020.

The most reactive interactions between allowed limits in zones separated by 8-in. exclusion areas occur at the zone intersections. As many as four zones may intersect. Interaction calculations were made for this case.

Allowable 10 kg spherical masses of ^{235}U metal plus 500 cc of water placed in each of the four zones at their point of closest approach had a k_{eff} of 0.735 each whereas the collection of all four had a k_{eff} of 0.751, indicating negligible interaction. (Metal spheres of fuel without the water may have a higher k_{eff} individually, but their interaction is less because of the smaller subtended solid angles.)

In the event that a fifth 10-kg mass of ^{235}U + 500 cc of water were dropped between the four allowed masses, the k_{eff} of the assembly would be increased only to 0.800. If this extra mass were dropped on one of the masses already present, the k_{eff} would increase to 0.877. All these calculations indicate that the interaction between allowed masses is safe, even in cases where an extra batch is involved.

The interaction of an accidentally double-batched sphere of metal fuel with the corner of a large concrete room, that is closely reflected on three sides with concrete, was examined using KENO calculations which yielded a k_{eff} of 0.84. Therefore the fuel load in the transfer cart will be able to pass around the cell without interacting hazardously with any of the masses in the working zones.

The central region of the Main Cell will serve as a storage and transfer (S and T) zone (see Fig. III-5). Transfer and storage facilities and their criticality limitations are as in ID-CHCS-A104.

Administrative controls are required to keep the fuel inventory in each zone within the limits allowed in Table III.5. Tag boards for each zone will be kept up to date reflecting each fuel transfer in and out of the zone. In addition, fuel transfers to or from areas outside the Main Cell will be recorded in a logbook for this purpose and the required transfer documents will be completed.

With these controls, compliance with the zone inventory limitations can be assured.

During fuel transfers between different zones within the Main Cell, a minimum of one-ft surface-to-surface spacing is to be maintained between the transferred fuel and any stationary fuel units. This requirement is to be controlled administratively. Compliance is assured by adequate training of operators and by frequent operational spot-checks by supervisors.

B. Radiation Safety

1. Radiation Protection System

The HFEF/N radiation protection system (RPS) incorporates radiation measuring devices for direct and airborne radiation. It provides continuous surveillance of the occupied operating areas and the stack effluent and gives warning to personnel by means of visual and audible local and remote alarms in the event of abnormal direct or airborne radioactivity levels. The RPS consists of the three separate subsystems described below.

a. Radiation Monitoring Subsystem

The radiation monitoring subsystem (RMS) is an area gamma monitoring network with detectors strategically located at fixed locations throughout the operating areas where personnel are normally present. Each unit of the subsystem consists of a fast-response ion chamber detector, a chassis equipped with a calibrated meter readout, adjustable setpoints for both visual and audible radiation alarms, provisions for instrumentation checkout and calibration setting, and an output signal to the RPS panel in the HFEF/N control room.

Gamma monitors installed for criticality monitoring have a unique audio and visual alarm which is standard for all ANL-W buildings and is tied into the ANL-W site-wide alarm system.

The instruments, procured from commercial sources, were subjected to quality assurance inspections and approval prior to installation. These inspections covered but were not limited to the following checks: operability of components, sensitivity, calibration of components, and compliance with specifications.

b. Air Radiation Monitoring Subsystem

The air radiation monitoring subsystem (ARMS) is an air particulate sampler system with detectors mounted in semipermanent locations. The detectors consist of a GM tube for beta-gamma detection or a solid-state silicon semiconductor for alpha detection. The beta-gamma constant air monitors were procured from commercial sources. The alpha constant air monitors were built by ANL-W using commercially available components. Both types of units have been tested operationally.

c. Stack Monitor Subsystem

The stack monitor subsystem (SMS) provides for the continuous monitoring of radioactive gases, iodine and particulate matter released from the HFEF/N main exhaust stack. The subsystem monitors ^{137}Cs , ^{131}I , gross

gas activity, ^{133}Xe , ^{85}Kr and gross alpha and beta particulates. The subsystem collects airborne particulates on a filter paper which is removed periodically and analyzed for gross alpha and beta activity and specific isotopes if a significant gross level is detected. The sample stream is isokinetically diverted from the stack effluent to the SMS and then returned to the stack. The SMS provides for local rate meters and a remote multipoint recorder for the seven channels. The stack effluent will be maintained below the guidelines established in ERDAM-0524 and -0510, taking into consideration the ANL-W site climatology and the stack system design. Grab samples will be obtained from the emergency stack; this sampling system will be activated by pressure in the emergency stack.

All three subsystems energize remote alarms in the control room. Remote readout (also in the control room) is provided through a calibrated multipoint stripchart recorder displaying the intensity of direct activity levels and the concentration of airborne radioactivity levels for the RPS. Local readout is displayed on a calibrated stripchart recorder on the air samplers in the ARMS, and on the SMS. Local readout for the RMS is given on a calibrated meter on each RMS chassis. Local audible and visual alarms are provided on each chassis of the ARMS, the RMS, and the SMS to indicate when the low- or high-level alarms have been tripped.

Alarms on the RMS and ARMS will be investigated and corrective action taken in accordance with the HFEF Emergency Plan and Procedures (see Section II.B for a summary of the Emergency Plan). If the SMS alarm indicates a release of activity, further action will be to confirm the isotopes and the concentrations, determine the consequences of the release, and to monitor and inform groups downwind of the release.

The number of units, sensitivity or range of detectability and alarm setpoints of the units in each of the three subsystems are consistent with the requirements of safe practices, HFEF/N operational requirements, and ERDA Health and Safety Manual chapters. Maintenance and calibration of all the units will be performed by the EBR-II Instrumentation and Control Group at scheduled intervals according to approved procedures.

2. Monitoring

a. Personnel Monitoring

Film badges or thermoluminescent dosimeter (TLD) badges are used for personnel monitoring. The type issued to an employee is determined by the radiological nature of his working environment. The monitoring frequency and maintenance of badge records are consistent with existing Laboratory policy and ERDA requirements. Pocket chamber self-reading or audible alarm dosimeters are also available as personnel monitoring aids for specific job assignments.

Hand and foot monitors are stationed in the building at permanent locations consistent with good contamination control practices. The monitors are capable of monitoring alpha, beta and gamma radiation. Local visual alarms are incorporated in the monitors.

The bioassay and whole-body counting program follows current Laboratory policy and ERDA requirements.

b. General Monitoring

Receipt of radioactive shipments, outgoing radioactive shipments, and intrasite radioactive shipments will be monitored by Radiation Safety personnel assigned to the facility. All transfers of radioactive materials within HFEF/N will be monitored unless it is deemed impractical. The practicality of monitoring transfers into the cells will be judged on a case-by-case basis. The level of radioactivity permitted in the occupied areas of the facility will be consistent with ERDAM-0524, "Standards for Radiation Protection" and Laboratory policy.

Routine area surveys will be conducted by Radiation Safety personnel.

3. Portable Radiation Detection Instruments

Hand-carried portable radiation detection instruments for alpha, beta-gamma, and neutron radiation are supplied, maintained, and calibrated by the ERDA-ID Health Services Laboratory. Floor monitors, provided by ANL-W, are also used for survey purposes. The gamma detection instruments are capable of monitoring high-level gamma (0 to 500 R/hr), medium-level gamma (0 to 50 R/hr), and low-level gamma (0 to 200 mR/hr) radiation. The medium-level and low-level instruments provide beta detection capability. Scintillation detection instruments provide alpha monitoring capability. Various neutron detection instruments are also available from ERDA-ID.

The capability for alpha and gamma spectral analyses is available through the ANL-W Analytical Chemistry Group.

4. Waste Handling

Gaseous discharge from Main Cell will be filtered through in-cell primary carbon-HEPA filter packs and secondary out-of-cell HEPA filter banks prior to discharge to the atmosphere. Gaseous discharge from the Decon Cell will be filtered through in-cell primary HEPA filters and secondary out-of-cell HEPA filters prior to discharge to the atmosphere. A stack monitoring subsystem (see Section 1.c, Radiation Protection System), will monitor this discharge air for gaseous activity and particulate contamination downstream from the filter units. The efficiency of the filters

will be tested periodically by the Aerojet Nuclear Company, and the change schedules will be in accordance with existing Laboratory policy and practices and ERDA standards.

If concentrations of airborne radioactivity smaller than the high-alarm levels are detected on the ARMS, appropriate action will be taken by the assigned Radiation Safety personnel. This action will include but not be limited to determining the concentration and rate of increase of concentrations of the airborne contaminant, identification of the isotopes, informing the facility management, identifying the source of the activity, assisting in the corrective action, and informing the facility management when conditions return to normal.

Tanks are installed for holdup storage of all suspect liquid wastes before they are pumped to an existing suspect waste evaporator for processing. The liquid waste sampling program in effect at HFEF/S will be expanded to analyze contaminants in HFEF/N liquid effluent. These analyses are performed by the Analytical Chemistry Group at ANL-W. Residue from the existing liquid waste treatment system is packaged for disposal in conformance with ERDA-ID regulations and disposed of at the ERDA-ID radioactive waste disposal site.

Solid waste generated by the plant will be packaged, handled, stored, and disposed of in a manner directed by experience and in accordance with Laboratory and ERDA requirements. The disposal site for solid radioactive waste is the ERDA radioactive waste disposal site, or the EBR-II high-level waste storage facility.

Secondary solid waste containers are not introduced into the cells; therefore, the potential for exterior surface contamination of the secondary solid waste container is minimized. Procedures for handling these waste containers will be in accordance with present waste handling policies. Further information pertinent to solid waste handling operations is given in Sections I.B.7.b and III.A.2, III.A.3, and III.A.4 of this report.

5. Contamination Control

a. Ventilation System

The building ventilating system design and airflow balance ensures airflow ventilation patterns from "clean" areas toward "hot" areas. The Main Cell employs a closed-loop argon circulation system. Radioactive and suspect systems discharge to the main stack after passing through HEPA filters. A stack monitor continuously monitoring radioactive gases, iodine and gross alpha and beta particulate matter is located downstream from the final set of HEPA filters prior to discharge from the stack. A local high-radiation alarm and instrument failsafe alarm is incorporated in this monitoring system, which also provides alarm and readout remotely in the control room. Area monitoring of airborne particulate radioactive material is accomplished by the air radiation monitoring subsystem described above.

All of the ventilation systems in the building have secondary operating control safeguards to permit automatic or manual control of all subsystems. Each system is equipped with the failsafe control mechanisms to maintain the required pressure differential between "hot" and adjacent "cold" areas. Interlocks are provided on the supply-fan start switches to prevent inadvertent overpressurization or reversal of airflow ventilation patterns.

In the event of building power outage, no serious radiation hazard to personnel or contamination control design violations are expected. Equipment essential to maintain ventilation pattern control is powered by the 200-kW emergency diesel generator. The diesel generator will be tested at full load periodically without interrupting the power supply to the emergency loads. Tests performed on the diesel generator show the time required for startup and transfer of power is less than 11 seconds. The automatic butterfly discharge valves for the building-laboratory exhaust fans and the cell exhaust fans are set to close at a slower rate than they open. The fan wheels also continue to coast after power fails. The closing and opening of the exhaust fan discharge valves combined with the coasting of the fan wheels result in a loss of exhaust from either system for a period less than 5 seconds in a transfer from normal to emergency power. The building laboratory and cell exhaust fan motors are energized as soon as emergency power is established. A refrigerated air supply fan motor and an evaporative cooled supply fan motor preselected to run on emergency power, are energized through a time delay relay, to start a maximum of 10 seconds after the exhaust fan motors are energized. With such provisions it is unlikely that there will be any reversal of flow so that air from contaminated or suspect areas will flow to clean areas during transfers to and from emergency power. One cell exhaust fan is on the backup power system.

The concurrent or simultaneous failure of normal power and all emergency power is highly unlikely. However, should this event occur, emergency procedures will be developed in accordance with requirements of the emergency plan given in Section II.B of this report. The emergency procedures would require building evacuation, protective clothing, and respiratory equipment for reentry, establishment of the reentry team roster, and determination of the airborne contamination concentrations. Correction of the conditions will be determined by HFEF/N management.

b. Liquid Waste Systems

Separate suspect liquid waste systems are provided for the "hot" and "suspect" areas. Two suspect retention tanks are provided for hold-up of this liquid waste to enable sampling for required radioassays.

Suspect change areas are located in the high-bay area (Room 304) adjacent to the hot repair room. These change areas serve

as a buffer zone and provide for personnel decontamination. Anticontamination or contaminated clothing are also removed here prior to entry into a cold area. The suspect change area in Room 304 is equipped with a shower and wash basin that discharge into the suspect hold tanks. There is one shower and one washbasin located in the men's washroom, which discharge into the suspect holding tanks.

c. Traffic Patterns

The building traffic patterns, the location of personnel monitoring equipment, and the administrative procedures are designed to provide contamination control. Hand and shoe monitors are located at each regular pedestrian entrance and exit, and in exits from highly suspect areas such as the hot repair area. The hand and shoe monitors are sensitive instruments capable of detecting alpha, beta and gamma activity.

The administrative controls for contamination control are provided through written procedures; appropriate posting of thresholds and exits of contaminated areas; use of buffer zones; directives for use of hand and shoe monitors and/or personnel surveys; and established action limits for decontamination of work areas, equipment, clothing and personnel.

d. Protective Clothing

Radiation safety directives will prescribe areas and conditions for the use of anticontamination clothing and respiratory equipment. Supplies of these items will be maintained at or near areas of probable use. Use of these supplies and conditions of use will be in accordance with safe practices and shall conform to guidance prescribed by the ERDA Health and Safety Manual chapters and Laboratory directives.

6. Criticality Alarm Systems

The system consists of criticality-type gamma-radiation monitors, warning horns, revolving blue-colored lights, location-indicating stations, a multi-channel tape-deck unit feeding the ANL-West Site all-call communication system, 13.2-V battery-type power supplies and associated equipment. Special gamma monitors are located in all areas where fissile material is stored or handled as required by ERDA Manual Chapter 050B. A waiver to the requirement for in-cell criticality monitors has been obtained because of the excessive ambient radiation backgrounds in the cells. The 4-ft shield walls of HFEF/N protect personnel from excessive exposures. The above system of criticality monitoring is consistent with requirements of CH-CA-050B.

7. Radioactive Material Transfers

Radioactive material shipments to or from the HFEF/N will be made in approved shielded containers, and with approved safe transport

equipment. Transfers within the confines of ANL-W which do not require shielding or heavy transport equipment will be in conformance with ERDA and ANL-W safe practices and procedures for the transfer of radioactive materials.

8. Shielding

The design criterion was that the cell shielding must attenuate the gamma radiation to a level of 1 mR/hr or less in normally occupied areas. The shielding integrity tests show that the high-density concrete walls do meet this criterion for normally occupied areas. However, the tests also show that under certain circumstances where the radiation level is very high, there are some areas, not normally occupied, where special administrative controls are necessary to limit personnel access. The elevation of the manipulator through tubes, considerably above head-height, is an example of such an area.

9. Guidelines for Health Physics

The ANL-W Health and Safety Manual and subsequent revisions thereto, Argonne National Laboratory safety policies, safe practices established and developed by the nuclear industry, and the appropriate health and safety chapters of the ERDA Manual together with the Chicago Operations Office implementing and nonimplementing supplements to the ERDA Manual will be used to develop plans, procedures and limits for the HFEF/N radiation safety program.

10. Conclusions

The radiation safety program, procedures, plans, and precautions are considered to be adequate to prevent excessive radiation exposure to on-site and off-site personnel resulting from normal and abnormal operating conditions in HFEF/N. The emergency plans are considered adequate to avoid radiation overexposures to reentry teams and other personnel under accident conditions.

C. Industrial Safety

Additional information relevant to an evaluation of industrial safety hazards, particularly fire, is presented in Section II.B, Emergency Plan.

1. Toxic Materials

All toxic materials brought into the HFEF/N facility will be subject to the control measures specified in the ANL-W Health and Safety Manual and to ERDA Manual chapter requirements. Safe-work permits, approved by the job supervisor, safety engineer, and health physicist, will be required prior to the commencement of work with toxic materials which have not received prior Health and Safety approval. This will include handling and

storage of acids and other dangerous chemicals. Acids will be used in small quantities for etching samples, both in the Main Cell within a containment-box enclosure and in the metallurgical laboratory sample preparation room. An eyewash and emergency shower are provided for out-of-cell emergencies.

Multigallon amounts of sodium, contained in large loops within shielded shipping casks, will be brought into the HFEF/N. The loops will be transferred into the Main Cell (argon atmosphere) and will be handled remotely. After removal from the loop, the sodium will be stored in sealed containers within the Main Cell until provision is made for its disposal.

Storage and usage of nonradioactive toxic materials at HFEF will be fairly limited in nature and the potential for large-scale hazardous releases is low. Toxic and flammable solvents, such as acetone and alcohols, will be stored in ventilated metal cabinets in the minimum amounts needed for operational purposes. All work with toxic materials will be subject to ANL-W Health and Safety Manual procedures to avoid any harmful exposures to personnel, and periodic industrial hygiene surveys will be conducted by Health and Safety personnel.

2. Physical Factors as Health Hazards

Precautions have been and will be taken to prevent hazardous exposure to noise and nonionizing radiation of personnel within HFEF/N in accordance with requirements of the ANL-W Health and Safety Manual. Noise levels were evaluated during the tests of some equipment and more measurements will be made by the ANL-W safety engineer as noisy equipment becomes serviceable. Significant noise sources include the emergency generator, hermetic blowers for the Main Cell argon recirculation system, and the service floor air compressor. The emergency generator running time is estimated at only about 50 hours per year. Where noise levels exceed the prescribed limits, appropriate actions will be taken to reduce the noise or, as a secondary measure, to provide personal ear protection or administrative control of exposure times to meet the requirements of the ANL-W Health and Safety Manual. Audiometric examinations will be given to personnel of selected ages during their annual physical examinations.

An evaluation will be made to assure that emergency signals are audible in all personnel access areas and are not masked by noise sources.

Nonionizing radiation sources, such as ruby lasers, may be used in HFEF/N, but operation will be subject to the approval of ANL-W Health and Safety after assurance of properly engineered safeguards and personnel protection.

All reasonable steps have been taken to minimize the possibility of personal injury from falls on floors, working surfaces, floor openings, stairs

and ladders. Stairways and other means of egress have been designed to meet the requirements of the Life Safety Code, National Fire Protection Association #101. Vertical ladders have been installed to meet the requirements of the American National Standards Institute (ANSI) Standard A 14.3, and handrails and toe boards around platforms and floor openings meet ANSI Standard A 12.1. The applicable paragraphs of the Occupational Safety and Health Standards (29 CFR 1910), promulgated under the Occupational Safety and Health Act of 1970, have also been met.

All permanently mounted equipment (cranes, elevator, transfer carts) for transfer of materials meets or exceeds the applicable codes or standards as follows:

- ANSI A 17.1 Elevators, Dumbwaiters, Escalators, and Moving Walks
- ANSI B 30.2 Cranes, Derricks and Hoists
- ANSI B 56.1 Powered Industrial Trucks

All have passed the required acceptance tests and will be subject to the inspections and maintenance specified in the above standards and in 29 CFR 1910. Cranes will be operated only by properly trained and qualified operators.

Special handling devices to assure proper safety will be developed for casks and other items. Casks will be kept as close to the floor as possible and transferred over and stored in only predesignated safe areas. Nonstandardized equipment will be handled under the direction of a qualified rigger. All rigging equipment (slings, chains, ropes, etc.) will be inspected periodically and proper use required to avoid damage from striking, scraping or overloading.

All electrical systems have been installed in accordance with the National Electrical Code (ANSI C1 and NFPA 70). All electrical equipment, including cord and plug-connected equipment, also complies with the above codes and standards as well as specific ones developed for individual classes of equipment. In the event of an electrical failure, adequate emergency power is available as required by the National Electrical Code and Life Safety Code. Lightning protection is provided in accordance with the requirements of NFPA 78--Lightning Protection Code.

No unusual mechanical hazards exist in HFEF/N. Compressed gases are installed and stored, in accordance with codes, standards and practices of the Compressed Gas Association, and floor-loading restrictions are posted as required by 29 CFR 1910. All steam, wastes, and water utilities meet or exceed the applicable codes and standards.

3. Ventilation and Air Cleaning

The building-laboratory exhaust system and the cell exhaust system in the second floor suspect exhaust equipment room are filtered through

HEPA filters installed so as to preclude bypass leakage. These filters will be tested for efficiency prior to installation and at least annually in situ with submicron dioctylphthalate aerosol. Corrective actions will be taken as needed to maintain a collection efficiency of at least 99.97%. Effluent is discharged through the main exhaust stack at an elevation of 10 feet above the upper roof on the north side. The discharge point for the emergency pressure vent stack from the Main Cell is at the east end of the building, 10 feet above the upper roof level. These discharge points are well away from the building air-supply intake, which is at ground level on the south side of the building.

Dual blower systems and emergency diesel generator power are provided to maintain greater than 50% of the design exhaust rate for the building-laboratory exhaust system and 100% of the design exhaust rate for the cell exhaust system under blower or power failure conditions. The negative pressure in the upper filter plenums will be continuously monitored and an alarm will sound in the Operations Office at a given pressure set point to indicate a potential low flow-rate condition. The emergency generator room ventilation is balanced to maintain a static pressure positive with respect to the adjacent corridor and the atmosphere at all times. When the generator is not running, supply air from the evaporative cooled system leaks through cracks to the surrounding building areas and the generating-cooling air inlet and exhaust plenum (017). The cooling air for the operating generator is controlled by three dampers which permit circulation of air from the generator room and/or the outside inlet plenum back to the room and/or the outside exhaust plenum depending on the damper positions which are controlled by a wall mounted thermostat.

Laboratory exhaust hoods have been balanced to approximately 135 feet per minute velocity across the open face of the hoods. Periodic scheduled performance tests will be made to detect deviations from the design air flow rates, and any necessary corrective measures will be taken to maintain satisfactory ventilation conditions.

The Main Cell argon atmosphere will be at a mean negative pressure of -2.5 inches of water with respect to surrounding areas by exhaust of up to 500 cfm of argon through in-cell HEPA and activated charcoal filters, followed by HEPA filtrations in the normal and cell exhaust system. In addition, the argon recirculation cooling system is filtered by HEPA filters in the Main Cell and sub-cell and a fraction of the recirculated argon passes through in-cell activated charcoal filters. By use of containment enclosures within the Main Cell atmosphere, gross contamination operations will be segregated from the Main Cell atmosphere.

Tests were carried out to determine that in-cell HEPA filters would withstand gamma radiation dosages in excess of 10^9 roentgens. Post-exposure tests with DOP aerosol showed that the filtration efficiency was

maintained. The gamma radiation dosage during the test was greater than the anticipated in-cell exposure. In addition, both the Main Cell and Decon Cell exhausts are refiltered by final HEPA filters in the suspect exhaust equipment room.

The truck lock air supply rate of 2480 cfm will provide dilution and removal of noxious vehicle emissions. In addition, administrative control will be used to minimize exhaust gas emissions into the truck lock by requiring that truck engines be shut off when not in use.

The upper level high-bay area has two unfiltered roof-peak exhausters at 3700 cfm each and a presently unfiltered exhaust hood discharging out through the south wall. This high-bay area is to be maintained as a clean area with the exception of the enclosed suspect repair room, hot repair room, equipment access, and suspect change room complex above the cells. These areas will be maintained negative with respect to the high-bay pressure and are on the HEPA filter exhaust system. Shipping casks will not be opened in the high-bay area until proper cell-transfer seals are established. HEPA filtration of the high-bay area is scheduled.

4. Fire and Explosion Hazards

The following applicable fire safety codes and standards have been followed in the design and construction of HFEF/N:

- NFPA-10 Portable Fire Extinguishers
- NFPA-12A Halon-1301 Systems
- NFPA-13 Sprinkler Systems
- NFPA-14 Standpipe and Hose Systems
- NFPA-30 Flammable and Combustible Liquids Code
- NFPA-70 National Electrical Code
- NFPA-80 Fire Doors and Windows
- NFPA-90A Air-conditioning and Ventilating Systems
- NFPA-101 Life Safety Code
- NFPA-203M Roof Coverings
- Uniform Building Code--International Conference of Building Officials

The amount of combustible materials in the facility will be held to the minimum necessary to function. Storage of other than laboratory-size quantities of flammable liquids is not anticipated. All combustible storage will be administratively controlled and will be restricted to protected areas.

HFEF/N has a fire alarm system (see Sections I.B.9 and II.B) comparable to other EBR-II area buildings. Alarms are sounded in the control room at the nearby ERDA fire department and all area bells to notify all ANL-W personnel. The system utilizes heat, products of combustion, and photoelectric types of detectors. A sprinkler system protects the truck lock and the emergency generator room. A manually operated CO₂ system is provided for protection in the cask tunnel and Decon Cell. First aid, fire extinguisher, and hose cabinets are strategically placed throughout the facility. Automatically actuated Halon systems are installed in the operations office and in the DAPCS Computer Room.

The secondary heat-transfer fluid for the Main Cell cooling system is mineral spirits with a flashpoint of 128°F (closed cup). The choice was based on stringent requirements for compatibility with the materials of the system, low freezing point, suitable pumping and heat-transfer characteristics, avoidance of formation of insoluble residues, and reasonable safety from the standpoint of fire, explosion, and toxicity. About 100 gallons of this fluid are in the system, and 100 gallons will be stored in the lower level control room. No fire could occur in the Main Cell on accidental release and ignition of the mineral spirits owing to the inert atmosphere. However, there is potential for a fire on release of the mineral spirits into air. The storage area is sprinklered and automatic controls are installed to control potential releases. A drop in level in the secondary coolant system expansion tank would actuate shutoff of the pumps for each chiller unit on release of a maximum of 26 gallons. Under normal operating conditions, the release would be limited to about 13 gallons. At the same time, an automatic valve would be opened for venting the expansion tank argon cover gas. It is considered that the control features included are adequate to prevent a fire or vapor explosion.

The Deoxo purifier for the Main Cell argon recirculation system is located in the east service floor area. Hydrogen gas is supplied to this equipment only after purging of the argon has lowered the oxygen content to 1% or less. No combination of hydrogen with this level of oxygen in argon can result in an explosion. The hydrogen feed is from a small compressed gas cylinder which is replenished from time-to-time from larger cylinders which are then immediately valved off. The cylinders will be moved only with their protective valve caps in place.

5. Inert Gases

The large quantity of argon gas in the Main Cell and the argon recirculation system presents a potential asphyxiation hazard to personnel in the improbable event of a major release into an occupied area. The argon atmosphere in the Main Cell is normally maintained at -2.5 inches of water pressure with respect to surrounding areas so in-leakage velocities would be very high through small openings. In the event of a large opening, such as uncoordinated removal of the six-foot-diameter round

hatch in the floor of the Main Cell, the cell exhaust rate would peak at about 500 cfm and control velocities would not be maintained, thus allowing argon to spill down into the area below. Operating procedures and administrative controls will be utilized to avoid such an occurrence. Since the transfer tunnel is not normally an occupied area, and since it is maintained at a slightly negative pressure with respect to neighboring areas, the argon is unlikely to flow to occupied areas and create a personnel hazard.

Immediate evacuation would be required in the east service floor area in the improbable event of a large-scale argon release from the recirculation blowers, oxygen and moisture removal equipment, or associated piping. The blowers are hermetically sealed and the components are rugged and are leak tested, so no apparent release hazard exists.

No requirement for entry of personnel into the Main Cell argon atmosphere is foreseen.

D. Main Cell Over and Under Pressure

The Main Cell of HFEF/N is a large gastight pressure vessel with a volume of approximately 69,000 ft³ (66,500 ft³ in-cell plus 2500 ft³ of out-cell ductwork and equipment). The pressure inside the cell relative to atmospheric pressure will change when the temperature of the gas inside the cell changes, when gas is added to or removed from the cell, or when the barometric pressure changes. Specifically, starting at design conditions (80°F and 12.2 psia) and assuming that argon is a perfect gas, one finds that the cell pressure will change 1 in. WG for each 1.6°F change in cell gas temperature, or for each 205 ft³ change in cell gas inventory, or for each 1 in. WG change in barometric pressure.

1. Normal Control Systems

Systems are installed that control and/or compensate for heat-load variations, for cell-gas inventory changes resulting from normal operations, and for normally expected barometric pressure fluctuations. These systems limit cell pressure to -1 in. WG on the high side to prevent outleakage, and -4 in. WG on the low side to restrict the rate of air inleakage. A brief description of these normal control systems follows:

- The Pressure-Temperature Control (Fig. III-9) varies the temperature of the cell gas by controlling the amount of cooling in order to maintain the cell pressure at the set point of controller dPIC-1 (-2.5 in. WG). Annunciation of the following off-standard conditions is provided: high pressure (-3/4 in. WG), low pressure (-6 in. WG), high temperature (105°F), and low temperature (65°F).
- The Normal Exhaust (Fig. III-10) vents gas from the cell to the cell-exhaust system when the cell pressure rises to the set

Fig. III-9. Pressure-Temperature Control System

Fig. III-10. Normal Exhaust System

point of controller dPIC-3 (-1 in. WG). The system is designed for a maximum flow from the cell of 500 cfm (referenced to 12.2 psi and 80°F). Gas being vented passes through both carbon and HEPA filters before leaving the cell.

- The Normal Argon Supply (Fig. III-11) feeds fresh argon gas to the cell from a liquid argon storage source when cell pressure falls to the set point of controller dPIC-2 (-4 in. WG). The system can supply gas at a maximum flow rate of about 50 cfm. The storage source consists of two 1500-gal tanks with a combined capacity of 340,000 scf of gas.

Fig. III-11. Normal Argon Supply System

2. Emergency Standby Systems

Two additional pressure control systems are installed; they are emergency systems that supplement the normal control systems described above. They do not function unless certain failures, malfunctions, misadjustments, misoperations, etc. occur, and then only if the occurrence has hampered the ability of the normal systems to respond to pressure changes or created a pressure excursion that exceeds the reaction capability of the normal systems. These emergency systems are

- The Emergency Argon Supply (Fig. III-12) feeds argon gas to the Main Cell from a gas cylinder storage source when the cell

Fig. III-12. Emergency Argon Supply System

pressure falls to the set point of differential pressure switch dPS-3 (-8 in. WG). The storage source consists of ten high-pressure (2400 psig) gas cylinders with a combined capacity of about 2200 scf of argon. The maximum rate of gas flow is about 60 cfm. The flow of gas to the cell will stop when cell pressure rises to about -6 in. WG.

• The Emergency Over- and Under-pressure Relief System

(Fig. III-13) vents gas from the cell or allows air to be drawn into it in order to prevent excessive pressure differentials that could cause structural damage to walls, windows and other components providing confinement of the cell atmosphere.

Fig. III-13. Over- and Under-pressure Relief System

Argon gas to be vented passes through the in-cell filters in the re-circulation system (consisting of 16 HEPA filters in parallel plus a carbon filter in series with two of the HEPA's), the pressure relief valve (PSV-1), and the oil seal pot (SP-2) before being discharged to the atmosphere from a stack reaching 10 ft above the high-bay roof. Venting of gas through the pressure relief system will start when the pressure at the seal pot (SP-2) exceeds $2\frac{1}{4}$ in. WG ($\frac{3}{4}$ in. WG relief valve cracking pressure plus $1\frac{1}{2}$ in. WG oil seal). Note that if the cooling fans are operating at this time, the pressure in the cell can be 1 in. WG to 3 in. WG higher than this, depending upon how many fans are operating and how dirty the filters are. The design relief pressure was selected considerably lower than the cell structural capability in order to reduce the potential for leakage of unfiltered cell gas to the building environment (also to avoid damaging pressure and control instrumentation).

Air will start to flow back into the cell through the pressure relief system when the pressure at the seal pot falls to about 22 in. WG below atmospheric pressure (11 in. WG relief valve cracking pressure plus 11 in. WG oil seal).

The nominal 12 in.-diam combination pressure and vacuum relief valve has a flow capacity of about 2000 cfm through either the pressure or vacuum port at a 3/4-in. WG pressure drop. Pressure drop due to flow through the system seal pot and ducting is estimated to be another 3/4 in. WG at the above flow rate.

This system is self-actuating and does not depend on proper operation or adjustment of other controls or equipment. It does, however, depend on maintenance of an unobstructed flow path between the cell and the atmosphere. In this respect the following considerations are important:

(a) The manual isolation valve at the inlet to the seal pot is locked open to prevent inadvertent shutoff.

(b) The in-cell filters must not become blocked with particulates. The most likely source of enough particulate material to create any possibility of blockage is a sodium fire. HEPA filters were recently flow tested at EBR-II after being loaded with sodium fumes. Flow characteristics of the tested HEPA filters changed from an original 1200 cfm at 1 in. WG to 150 cfm at 2 in. WG pressure drop after being loaded with 4 lb of sodium fumes. A sodium fire large enough to load all 16 in-cell HEPA filters to the extent described above would require a pool containing 160 lb of liquid sodium and a cell atmosphere containing at least 4% oxygen. Since either of these conditions is highly unlikely, the simultaneous occurrence of both and thus filter blockage is not considered credible.

(c) During construction, a swarm of flying ants found their way into the pressure relief stack and died by the thousands in the stack and in the seal pot. It is difficult to predict the likelihood of this happening again or the amount of blockage that could be caused by the mixture of insect bodies and seal pot oil. The seal pot will be inspected regularly so that operating personnel can take corrective action should anything like this happen again. A cover with screen has been installed to prevent flying ants from entering the stack.

(d) A rainhood is installed at the top of the pressure relief stack. This rainhood (see Fig. III-14) provides for straight upward rather than horizontal or angular downward discharge in order to improve the dispersion of gases discharged from the cell. It appears possible that some blockage of flow through the rainhood could result from snow or ice, or from the nest-building activities of birds. The probability that this blockage could be severe enough to impair the ability of the pressure relief system to prevent structural damage to the cell is very low.

Fig. III-14. Rainhood on Pressure Relief Stack

3. Mechanisms for Pressure Changes

Certain mechanisms exist that can cause perturbations in cell pressure. Estimates of maximum gas flow rates and the extent of cell pressure fluctuations caused by each are given below.

a. Barometric Pressure Change

Barometric pressure changes have an inversely proportional effect on cell pressure. The maximum recorded barometric pressure change at the INEL in a 24-hr period is 1.0 in. Hg (13.6 in. WG) and that in a one-hour period is 0.1 in. Hg (1.36 in. WG). Based on this latter figure, a gas flow rate of about 5 cfm into or out of the cell or a cell gas temperature change at the rate of 2.2°F/hr would compensate for the maximum rate of barometric pressure change.

The minimum recorded barometric pressure at the INEL is 24.26 in. Hg (329.8 in. WG) and the maximum is 25.69 in. Hg (349.3 in. WG). This difference of 19.5 in. WG would result in a cell pressure that could vary within extremes of -23.8 and +18.8 in. WG if no pressure control were exercised during the barometric pressure swing. However, a total flow of about 4000 ft^3 of gas into or out of the cell, or a 32°F cell gas temperature change would completely compensate for such an extreme total barometric pressure change.

b. Loss of Cooling

Failure of the Main Cell cooling system could result in a rise in cell temperature and possibly an increase in cell pressure above the normal high limit (-1 in. WG), depending on the extent of failure, the rate of temperature rise, and the operability of the normal exhaust system. Only complete loss of cooling, the most serious failure, is considered in this discussion. Such a loss could stem from a number of different causes. Each mode of failure has a different degree of credibility and a slightly different effect on cell gas flow and is therefore discussed separately below. Since the cell is a very complex structure that defies an easy thermal analysis, the most conservative assumptions were used in arriving at estimates of the rate and extent of the temperature rise in the cell gas. Therefore, the actual gas flow rates due to loss of cooling are probably considerably less than predicted below.

(1) Loss of Normal Power. Periodic loss of normal power has occurred at ANL-West in the past and may occur in the future. Since the cooling equipment for the Main Cell is not connected to the emergency power supply, all fans, pumps, and compressors will stop when the normal power supply fails.

Most in-cell heat loads, including normal lights, experimental equipment, circulating fans, etc., will be deenergized on loss of normal power, but they will be warm at the time of the power outage and some heat transfer from these items to the cell gas will continue until they cool. Some heat loads such as the emergency lights (7.5 kW), the subassembly storage cooling blowers (20 kW design), and the

purification loop compressors will continue because they are energized by emergency power, and transfer of radioactive decay heat (13 kW) from irradiated subassemblies to the cell gas will also continue.

The temperature of the cell gas will rise at the highest rate in the period right after loss of normal power when lights and equipment fed from the normal power source are still warm and when heat transfer from the cell liner to the cell gas is highest because of the large temperature difference. (It is assumed for this analysis that for some unspecified reason, the temperature of the cell gas has been reduced to 70°F at the time of power outage, even though the normal operating temperature is expected to be closer to 90°F most of the time.)

It is estimated that temperature would rise at an initial rate that cannot exceed 7°F per minute and would continue to rise at an ever decreasing rate until a temperature of about 115°F was reached in two hours or less. When the cell gas reaches this temperature, heat transfer from the gas to the cell walls will equal the heat input to the cell gas. Any additional increase in gas temperature will be due to cell wall heatup. These massive walls will change temperature very slowly. For example, if heat input to the cell gas (from emergency lights, the subassembly cooling blower and radioactive decay) were completely absorbed by the cell walls, it would take over 13 hours to change the temperature of the walls 1°F.

If the temperature of the cell gas should indeed rise at the maximum estimated rate, gas would have to be vented from the cell at a flow rate of about 800 cfm in order to prevent an increase in cell pressure. This flow rate is greater than the venting capacity of the normal exhaust system so a short-lived buildup of pressure in the cell (3 to 4 min duration) and discharge of cell gas through the emergency pressure relief system could occur. (In the entire eight-year operating history of HFEF/S, which has a similar pressure relief system, gas has never been released through the emergency system under any circumstances, including loss of normal power.) Cell pressure would return to below atmospheric when the rate of cell gas temperature increase had fallen to about 4.0°F per minute or less.

A total of about 5500 ft³ of gas would have been vented from the cell by the time the temperature of the cell gas reached the relatively stable 115°F. An additional 4000 ft³ of gas would be vented should the power outage last long enough for the cell gas temperature to reach 140°F. About 500 ft³ of this gas would be vented through the pressure relief system (HEPA filtered) with the remainder vented through the normal exhaust system (HEPA plus carbon filters in-cell, additional HEPA filters out-of-cell).

(2) Loss of Both Normal and Emergency Power. This condition could arise from a failure of the emergency diesel generators to start on loss of normal power. The cell gas temperature excursion caused by this condition

should be somewhat less severe than that described for the condition above, because the heat load from the emergency lighting is eliminated. Figure III-15 shows the estimated cell gas temperature and the total cell gas vented for the first 100 minutes after the loss of cooling.

Fig. III-15. Cell Gas Temperature and Volume of Gas Discharged to Atmosphere vs. Time after Loss of Normal and Emergency Power. Assumes cell gas at 70°F at time of incident and that all gas is discharged through the emergency relief system. ANL Neg. No. 103-R5072.

The cell exhaust system will not be operational during this period and all gas vented from the cell will be vented through the pressure relief. The only alarm that will sound will be in the EBR-II Reactor control room signaling loss of power.

(3) Failure of Cooling Equipment. Loss of cell gas cooling due to failure of cooling equipment is unlikely to occur because of the redundancy designed into the Main Cell cooling system. That is, the cooling system will prevent temperature excursions unless two identical items of equipment fail simultaneously (i.e., both fans, both pumps, both refrigeration compressors).

The rate at which the temperature of the cell gas rises could be greater upon failure of cooling equipment than upon loss of power because all in-cell heat loads remain energized. Specifically, failure of both circulating fans would be the worst case. When the fans are operating a certain amount of heat transfer from the cell gas to the cooling coil, the fluid and the duct heat sinks continues for a period after failure of the cooling pumps or the refrigeration compressors. However, if the fans have failed, this heat transfer does not take place.

It is estimated that the rate of cell gas temperature rise resulting from the simultaneous failure of both circulating fans cannot exceed $9^{\circ}\text{F}/\text{min}$. Should the cell gas temperature actually rise at this maximum rate, gas would have to be vented from the cell at a flow rate of about 1100 cfm in order to prevent an increase in cell pressure. Since this flow rate is greater than the venting capacity of the normal exhaust system, a short-lived buildup of pressure in the cell (less than 10 min duration) and discharge of cell gas through the emergency pressure relief system could occur (see Fig. III-16).

Since both high-pressure and high-temperature conditions are annunciated, it is expected that operating personnel will switch off all nonessential in-cell lights and equipment soon after a cooling system failure, thus limiting cell temperature to an equilibrium value of about 140°F (as in the case of power loss). However, in the incredible circumstance that these heat sources remain energized for an extended time (four days or more), cell temperature could conceivably climb to as high as 170°F . A total of about 13,000 ft^3 of cell gas would have been vented to the atmosphere during this temperature excursion (70 to 170°F).

(4) Failure of Cooling System Control. Cell gas temperature excursions can also result from any control system misoperation or malfunction that prevents cooling or falsely signals that cooling is not required. For example: (a) Loss or blockage of instrument air to or control signal from either temperature transmitter EP/I-1 or temperature controller TIC-1 will prevent opening of cooling fluid control valves (when the cell is operating in the temperature-control mode). The same problem could result from instrument malfunction while a smaller increase in cell temperature could result from instrument misadjustment (120°F maximum). (b) The conditions described above with respect to temperature transmitter TIT-5, temperature controller TRC-1, or step controller SC-1 will prevent operation of the refrigeration system. (c) Loss of electrical power to certain

3-way solenoid valves can prevent opening of automatic valves in the cooling-fluid piping and/or gas-circulating piping. (d) Loss of cooling can result from the inadvertent switching to the off position of cooling system equipment hand controls located on the main control panel and/or circuit breakers located in the motor control centers.

Fig. III-16. Cell Gas Temperature and Volume of Gas Discharged to Atmosphere vs. Time after Complete Loss of Cooling. Assumes cell gas at 70°F at time of incident and no power outage. ANL Neg. No. 103-R5073.

In the worst case, loss of cell cooling due to control failure should affect cell temperatures, pressures and vent flow rates essentially as described in the previous section for loss of cooling due to failure of cooling equipment.

c. Excessive Cooling

A decrease in cell gas temperature and probably a decrease in cell pressure would result from a failure of the temperature control system to prevent excessive cooling. This condition could result from the misadjustment or malfunction of cell-temperature controller TIC-1 or possibly from the malfunction of cell-temperature controller TIC-1 or possibly from

the malfunction of cell-temperature transmitter E/P-1. In the worst case, this would result in cell gas cooling being turned on full blast at a time when: (a) in-cell heat loads are nil (i.e., no lights, no irradiated subassemblies, no in-cell equipment operating, etc.); (b) cell gas temperature and cell liner temperature are both 100°F; (c) cooling fluid supply temperature is at its coldest (0°F supply temperature is possible if controller TRC-1 is operated on manual set point and adjusted for 10°F return temperature).

Although unlikely to occur, the combination of conditions postulated above would result in a rapid decrease in cell gas temperature. The rate of decrease would be greatest at the start of the temperature excursion causing contraction of the cell gas at a rate that exceeds the combined capability of the normal argon supply system and the emergency argon supply system to add fresh argon to the cell, thus resulting in a decrease in cell pressure. Since both low pressure and low temperature are annunciated, it is expected that cooling would be reduced by operating personnel soon after the temperature excursion begins. However, if for some reason this were not done, the cell pressure would continue to decrease until air was drawn into the cell through the pressure relief oil-seal pot and the vacuum port of the pressure relief valve. (Air will start to flow into the cell when pressure at the seal pot falls to -22 in. WG. This corresponds to -19 in. WG in the cell, assuming a pressure drop of 3 in. WG due to flow through cooling system filters and ducts.)

The rate of temperature decrease gradually slows down because the amount of heat added to the cell gas from the cell liner and circulating duct increases as the cell gas gets colder while the heat removal capability of the cooling system simultaneously decreases. When the rate of temperature change is 0.8°F/min or less, no additional air will be drawn into the cell. The system is capable of reducing the temperature of the cell gas from 100 to about 64°F after 5 min of operation under the worst case conditions defined above. At this time about 500 ft³ of fresh argon would have been added to the cell and about 1000 ft³ of air would have been drawn into the cell through the pressure relief system. Since the rate of temperature change would have fallen below 0.8°F/min at this time, no additional air will flow into the cell. The oxygen level in the cell would increase to about 0.3% as the result of the air introduced into the cell for pressure relief.

The cell gas temperature would continue to fall at an ever-decreasing rate until equilibrium is reached at about 40°F. If at the same time, both argon supply systems were to fail, a total of about 4600 ft³ of air could be drawn into the cell as a result of this temperature excursion, raising the oxygen level in the cell to about 1.4%.

d. Gas Supply to Cell from Liquid Argon Storage Tanks

There are a number of ways in which gas from the liquid argon storage tanks can find its way into the cell. These are:

(1) Normal Argon Supply for Pressure Control. Argon gas (20 psig) is fed into the cell through pressure control valve ROV-1 as required to make up for barometric pressure swings or to replace gas removed from the cell (for gas sampling, containment box exhaust, etc.). This pressure control gas supply is expected to be intermittent and normally small, especially since the gas inventory and barometric pressure changes may be compensated for by gas supplied to the cell from other sources (i.e., pneumatic tools, purge, etc.), or by cell gas temperature changes. In any case, the flow is limited by piping and valve restrictions to a maximum of about 50 cfm.

(2) Transfer Lock Gas Fill. Gas connections (1 psig) are provided for filling the transfer locks with argon gas after they have been evacuated. Gas from this source can only get into the cell as a result of the failure of an interlock to prevent opening of the purge valve when the transfer lock hatch cover is open. The maximum flow rate is about 30 cfm.

(3) Equipment Purge. Valved and capped piping connections are provided for purging the Main Cell argon atmosphere equipment prior to and after servicing. These can be connected through hoses (and pressure reducing valves where required) to the 20-psig normal argon supply headers. Normally, this gas is vented to the cell exhaust system and can get into the cell only as a result of misoperation of isolation valves. Maximum flow rate is about 30 cfm.

(4) Purge of Cell Pressure-sensing Lines. A small but continuous flow of argon is provided through the cell pressure-sensing lines in order to reduce the migration of radioactive particulates from the cell to the pressure-indicating and control instruments. The normal flow rate is about 0.04 cfm.

(5) Leakage from Seal-monitoring System. A continuous but very small flow through seals, windows, manipulators, etc., is maintained at a normal flow of less than 0.01 cfm with maximum flow possible of less than 2 cfm.

(6) Rabbit Tube Transfers. Argon gas at 100 psig is used for the rapid transfer of irradiated specimens into and out of the cell through two rabbit tubes. The cell gas inventory will change very little during a transfer because the motivating force for the flight of the rabbit through the transfer tube involves both a pressurized gas push and a vacuum pump pull. It is estimated that the effect per transfer will be a net reduction of one or two cubic feet of cell gas. However, misoperation or malfunction of valves or controls could result in a continuous flow of about 10 to 20 cfm of gas into the cell.

In the event of a failure of any single system above, the maximum rate of flow of argon into the cell would be 50 cfm. Even in the

incredible circumstance where all systems fail simultaneously, the combined rate of flow from all sources is limited by piping, valving and vaporizing restrictions to less than 300 cfm. This is considerably less than the capacity of either the normal exhaust system (500 cfm) or the pressure relief system (2000 cfm). It is thus concluded that the Main Cell cannot be harmfully overpressurized.

e. Gas Supply to Cell from Emergency Storage Cylinders

Flow of gas from the emergency argon storage source is automatically actuated when cell pressure falls to -8 in. WG. This flow, which is limited to about 50 cfm by valve and piping restrictions, can be inadvertently initiated by the switching of a hand control located on the main control panel (CP-1) from the "AUTO" position to the "ON" position. Since this flow rate is well below the venting capabilities of either the normal exhaust system or the pressure relief system, no buildup of cell pressure is expected from this cause.

f. Gas Supply to Cell from Other Sources

High pressure argon gas (100 psig) is fed through an extensive system of valves and tubes to in-cell headers that provide room for the connection of as many as 200 pneumatic tools. Equipment that may require gas for bearings, clamping, cooling, etc., such as the profilometer, VAD and SLSF cutoff machine, is also connected to these headers. The intention is to limit the simultaneous use of gas for equipment and tools so that the flow rate does not exceed 20 to 40 cfm. Overall usage is expected to be quite intermittent, especially during the early days of operation. A recirculating gas compressor has been installed to supply gas to in-cell pneumatic tools and equipment; when this compressor is used argon gas from the liquid storage source for this purpose would be discontinued.

Spare tubes have been provided in the pneumatic tool system penetrations. These tubes are connected to the in-cell pneumatic tool headers and are capped off outside the cell. One or more of these tubes may be connected at some future time to a presently undefined source of gas. The tubes are suitable for use at a pressure of 1500 psig but gas usage, flow rate and total storage is expected to be small and to present no potential cell-pressure buildup problems.

g. Removal of Gas from Cell

There are a number of ways in which gas can be removed from the cell. They are:

(1) Normal Exhaust. Gas is pulled out of the cell through HEPA plus carbon filters and an oil seal pot by the cell exhaust system fans whenever the normal exhaust valve ROV-3 opens. This valve starts to open

automatically when the cell pressure rises to about -1 in. WG, but it can be caused to open and remain open at lower cell pressures by malfunction or misadjustment of the cell exhaust controller dPIC-3, or by manual operation. However, should this occur, the cell pressure cannot be reduced below about -10 in. WG because this is the lowest suction pressure that the cell exhaust fans can achieve. Flow from the cell is limited to a maximum rate of 500 cfm by a device that prevents ROV-3 from opening wide. This rate of flow is gradually reduced as the cell pressure approaches fan suction pressure.

(2) Analytical Gas Sampling. A small quantity of cell gas is continuously pumped through oxygen and moisture analyzers and then discharged to the cell exhaust system. The diaphragm type pumps that move this gas are capable of very low ultimate pressures but the flow rate is so low (approximately 0.06 cfm total) that the effect on cell pressure is very slow (1-in. WG change in 60 hr). Further, the normal argon supply system would prevent this from occurring.

(3) Containment Box Exhaust. Gas is pumped from the containment box as required to keep it at a slightly lower pressure than the cell in order to prevent leakage of gaseous contaminants from the box into the cell. It is estimated that the leak rate into the containment box at 1/2-in. differential pressure will be about 0.1 cfm or less. However, the two diaphragm-type pumps provided have a combined capacity to remove about 2 cfm of gas from the box should a big leak develop or a transfer hatch be opened. This higher flow rate could also result from malfunction, misadjustment, or misoperation of the control system. A relief valve has been installed to prevent structural damage to the containment box by relieving gas into the box from the cell should this problem occur. The pressure control systems can easily compensate for this outflow.

(4) Transfer Lock Vacuum Pumping. Two large vacuum pumps (300 cfm nominal each) are provided to remove air or potentially contaminated argon from any of three transfer locks during the process of transferring material or equipment into or out of the Main Cell. Normally, only very small changes in cell gas inventory result from these transfers because fresh argon gas is supplied directly to each lock to replace the gas that is removed from the lock during the pump-down cycle. The pressure in the lock is equalized with cell pressure through a remotely operated valve and an equalizing line before the in-cell hatch cover is opened. The only gas flow into or out of the cell is due to the slight imbalance in pressure that might exist prior to the equalizing operation.

The two vacuum pumps are interlocked with the cell low-pressure alarm in such a way as to shut them off when the low-pressure indication (-6 in. WG) is reached. At this point, the argon supply system will then restore the cell pressure to normal.

(5) Rabbit Transfer Tube Vacuum Pumping. As described in paragraph d-7 above, there will probably be a one- or two-cubic-foot outflow of cell gas during each transfer. However, misoperation or malfunction of valves or controls could lead to about 35 cfm of gas being pumped continuously out of the cell. This flow rate is less than the makeup capacity of the normal argon supply or the emergency argon supply; therefore, no pressure excursion is expected from this cause unless and until the storage tanks and cylinders are emptied. Under these conditions, the pumps could reduce the cell pressure to -22 in. WG at which point the pressure relief system would automatically prevent any further reduction of pressure.

4. Conclusions

As a result of the above evaluations of potential mechanisms for over- or under-pressuring the Main Cell, it is concluded that sufficient protective mechanisms exist to guard against harmful over- or under-pressure conditions. Even in the case of failure of the worst kind (see paragraphs 3.b(1) and 3.b(3)), the cell would suffer no damage, but some 14% of the cell argon could be vented to the atmosphere. Analyses of the results of this occurrence coupled with various accident conditions are presented in Section IV.C.

E. Systems Evaluations

In this section each major system, along with its subsystems, is analyzed with respect to the effects of failure of the system on the safety and operability of HFEF/North. In this report, a major system is one whose loss due to failure or component malfunctions might affect the safety of operations within the facility. Individual pieces of equipment such as in-cell examination instruments, although most important to the facility operations, are not considered systems since the equipment may be removed from, or repaired within the facility without affecting the facility's safety.

1. Service Water and Fire Protection System

Under normal operations, water for the Argonne-West site is pumped from deep wells by one of two pumps, the other being a standby. The water is pumped to a 200,000-gallon storage tank located immediately east of HFEF/N. The stored water flows by gravity to three feed pumps which operate automatically in sequence to maintain a 100-psig line pressure. The three pumps are driven by electric motors operating on normal electric power only. If a power failure occurs, a diesel-driven fire pump starts automatically and maintains water pressure for the site. An underground piping loop provides service and fire protection water to the ANL-West facilities, which include the HFEF/N. The water distribution loop provides water from either of two directions to HFEF/N through two short underground pipes.

One pipe supplies the fire protection system and the other pipe supplies the service water system. The fire protection system supplies the fire-hose cabinets on all floors, the sprinkler systems in the generator room and the truck lock, and one fire hydrant on the north exterior of the facility. The service water flows to the potable hot and cold water system, the laboratory hot and cold water system, the hot water heating system, the cooling water system, and the chilled water system.

In case of a break in the pipe supplying fire protection water to HFEF/N, temporary hose connections from nearby fire hydrants to the facility could be installed until the broken pipe was replaced or repaired. There are twin fire connections in the exterior wall of the building where hose connections could be made in minutes by the local fire department to maintain the integrity of the fire protection system.

There is high reliability in the service and fire protection system, which includes the two deep-well pumps, the large storage tank, the feed pumps, the fire pumps, and the loop network. In fact, in the history of the ANL-West site (approximately 13 years), there has never been a major loss of water pressure in the entire underground network. If an electrical power failure occurs, the diesel fire pump must start in order to maintain the line pressure. In 52 weekly tests the diesel started in less than 5 seconds on all occasions. Past performances of the system and its components confirm a high degree of reliability and availability of the system.

2. Carbon Dioxide and Halon Fire Protection Systems

The Decon Cell is protected from fire damage by a system which directs carbon dioxide through several remotely-handled nozzles to the source of a fire within the cell. In addition, there is a carbon dioxide system in the cask tunnel on the service floor. An automatically actuated Halon system is installed in the Operations Office and in the DAPCS computer room. Halon is a refrigerant-type material that smothers a fire. It is effective on class A, B, and C fires as defined by the National Fire Protection Association.

The Halon is stored in a tank on the service floor along with the valve banks and nitrogen pressurizing system. A failure of the Halon system (as for example loss of pressure because of a leak in the tank, piping or components) could affect the safety of operations in the facility. A loss of pressure in the system, however, would be sensed by a low-pressure switch which actuates the fire alarm system.

3. Potable Water System

The washrooms, drinking fountains, and cooling water lines for the instrument air compressor are served from the potable water system. The

instrument air compressor is normally on stand-by while instrument air is provided by the plant air compressor. The plant air compressor and its after cooler are supplied with water from the cooling tower, and not from the potable water system. Therefore, it follows that a loss of the potable water system would not cause a loss of instrument air and thus would not affect the safety or operations of the facility.

4. Laboratory Water System

The purpose of the laboratory water system is to furnish a separate and distinct source of water to the Decon Cell, laboratory hoods, laboratory sinks, and other suspect areas and equipment. A failure of the system would not endanger the safety of operations within the facility.

5. Hot Water Heating System

The laboratory water system furnishes makeup water for the hot water heating system. The water is heated in a steam-to-water heat exchanger and circulated by two centrifugal pumps. The hot water delivers secondary heating to the facility through the reheat coils in the ventilation system and through the fin-tube radiators on the peripheral walls of the facility. Except in extremely cold weather, failure of the hot water heating system would not affect the operations or safety of the facility.

6. Cooling Water System

The refrigeration units for both the facility air conditioning system and the argon cooling system are cooled by the cooling water system. Also cooled are the precooling coils in the ventilation system, the vacuum pumps and the plant air equipment. The water is cooled in a two-cell cooling tower and circulated through the system by one of two centrifugal pumps. The use of two strainers in the system permits easy cleaning and maintenance of one strainer while the other is on the line.

Facility operations could be curtailed if there were a failure in the cooling water system. If the argon cooling system were denied cooling water, it might be difficult to maintain pressures and temperatures within operating tolerances in the argon cell. The most probable cause of failure in the system would be icing of the cooling tower or its components during extremely cold weather. There is built into the system, however, a heat exchanger for applying false heat loads to the cooling tower. There are also heaters in the basin of the tower to prevent freezing of the residual water. Since a system failure could affect the operation of the Main Cell, even though a system failure is remote, a backup method similar to that in use in the EBR-II system has been installed. It consists of a short spool piece which connects the service water with the cooling water system. A valve downstream opens to the clear water drain, thus, providing an emergency, once-through, backup cooling system.

7. Chilled Water System

The cooling coils in the ventilation system and the fan-coil units are served by the chilled water system. Failure of any components in the system would cause a loss of air conditioning in the facility. Loss of air conditioning for a long period of time during a hot, humid spell could cause malfunctions in instrumentation systems; however, long down-time due to system failure is unlikely. There are two refrigeration units (chillers) and two circulating pumps in the system to ensure high reliability of the major components. Cooling coils, fan coil units and other components are easily repaired or replaced, assuring high system availability.

8. Clear Water Drain System

Water collected from clean sources such as water coolers, floor drains in clean areas and the plant-air compressor after-cooler flows to three, duplex sump-pump units on the service floor. When the sumps are full to the limit switch setting, one of the duplex pumps delivers the clear water to a drainage ditch north of the facility. The water then flows to a collecting pond in the northwest quadrant of the site. Two of the three units are on both normal and emergency power.

Bursting of a pressurized water pipe during an off-shift, if undetected, could cause flooding conditions in the basement despite the fact that all three sump pumps were operating. Time delay switches on the duplex sump pumps actuate the building alarm system when excessive operation of either or both pumps is detected.

The water flowing in the ditch to the collecting pond is periodically monitored to ensure that waste materials harmful to the environment are not discharged in the clear water drain.

9. Sanitary Sewer System

Sanitary sewage from all water closets, urinals, and nonsuspect lavatories flows from the facility to a lift pump east of the facility. The lift pump delivers the sewage to the sewage lagoons in the northeast quadrant of the site. All plumbing work conforms to the requirements of the National Plumbing Code and has high reliability. Failure of the system or any of its components, although a nuisance, would not affect the operations or safety of the facility.

10. Suspect Liquid Waste System

Two separate classes of waste flow into the suspect liquid waste system; one class from the Decon Cell is known to be radioactively contaminated, and the other class from laboratories, hoods, showers and certain other drains is suspected of being contaminated.

Contaminated liquid waste from the Decon Cell storage pits and transfer tunnel floor area collects in a sump located in the transfer tunnel below the Decon Cell and is then pumped to the Decon Drain Holdup Tank (300). Contaminated liquid waste from the Decon Cell spray chamber collects in a sump located in the Decon Cell floor and is then pumped through two in-line filters to tank 300. Other liquid wastes with a high probability of being contaminated above permissible disposal limits (e.g., from hot repair area, decon showers, etc.) are drained into tank 300. When the tank is filled, the contaminated liquid is sampled and pumped through underground piping to the retention tanks and evaporator in the Laboratory and Office (L&O) Building, or pumped to a truck connection in the truck lock.

Suspect liquid waste is collected in the Laboratory Drain Tank (301). When the tank is filled, the waste is sampled and pumped to either industrial waste or to the L&O Retention Tanks or the Truck Loading Station (Ref. pp. 1.38, 1.39).

Both tanks are equipped with local liquid-level indicators and high-level alarms which sound an audible alarm in the operations office and in other areas. Interlocks protect the transfer pumps by preventing pump operation without adequate liquid level in each tank. The tanks and vents are maintained at a negative pressure with respect to the tank room, through a connection to the Building Lab Exhaust System. If, for some reason, the high-level alarms should fail or are not acted upon, overflow from the Decon Drain Holdup Tank flows into the Laboratory Drain Tank. The overflow from the Lab Drain Tank, if not acted upon, is directed to a sump in the depressed floor of the tank area. The floor is depressed to collect any leakage from the tanks. A drain in the depressed floor connects to the floor sump from which a sump pump circulates the leakage or overflow back into the Decon Drain Hold-up tank. Two pumps, one associated with each tank, circulate waste water for sampling and transfer the water to the L&O Building or to the Truck Lock.

The critical components in the suspect waste system are the transfer tunnel and decon drain sump pumps. Failure of the pump(s) would halt decontamination operations in the Decon Cell. The transfer tunnel sump pump is supplied with normal and emergency electrical power. Lights on the system operating panel indicate that the pumps are on. A screen in the spray chamber floor drain prevents large pieces of contaminants from dropping into the Decon Cell drain sump or clogging the in-line filters.

A highly unlikely failure of the tank, pump or other components, or a fracture of any piping could cause a radiation hazard in the area of the failure. The Health Physics Section's surveillance should detect the radiation hazard with the radiation monitoring system. A constant air monitor is installed in the immediate vicinity of the suspect waste storage area. Operations in the area would cease until the failure was repaired and the area decontaminated.

11. Steam and Condensate System

Steam for site heating and processing is generated in three oil-fired boilers in the EBR-II power plant. For additional capacity and reliability a fourth boiler will be added in the near future. Steam at 175 psig flows from the power plant through a single, underground header to the HFEF/North. Steam condensate is collected and pumped back to the power plant by a pair of duplex condensate pumps. In the facility, the steam pressure is reduced for heating and processing purposes. Steam is used in the pre-heat coils and hot water converters in the ventilation system, in the hot water heaters, in the Decon Cell, and in the cooling-water heater.

The most serious failure which would affect the facility operations, but not necessarily the safety, would be a rupture in the underground steam piping when the outside temperature was below freezing. There would be a loss of steam pressure in the preheat coils of the ventilation system, which in turn would result in a drop in air temperature downstream from the coil. A low temperature sensor in the downstream duct will actuate an audible alarm in the annunciator panels. After the alarm is acknowledged, manual adjustments can be made to the supply-air and exhaust systems to prevent freezing damage by the personnel on duty.

12. Plant Air System

The compressor in the plant air system delivers air to the breathing air system, the instrument air system under normal operating conditions, and to the laboratories and processing equipment. The air flows from the compressor to a receiving tank through an after-cooler, moisture separator, one of two parallel air dryers, and a filter. The plant air is high quality, clean, dry, and oil-free; it is suitable for breathing and for use in instrumentation systems. A failure of the plant air system would not affect the operations or safety of the facility. Low air pressure in the system is sensed and annunciated as part of the building equipment alarm system. The instrument air system automatically switches on if the plant air pressure drops. To add to the reliability of the instrument air system, the plant air compressor in HFEF/S has been connected by underground piping to the plant air system in HFEF/N.

13. Instrument Air System

The pneumatically-actuated instruments on the process equipment and in the ventilation system are operated from the instrument air system. Instrument air is normally supplied by the plant air system, but during an electrical power failure or a loss of pressure of the plant air system, the instrument air compressor is activated. The instrument air compressor operates on both normal and emergency electrical power.

As described in the plant air system narrative, added reliability of the HFEF/N plant air and instrument air systems is available with the interconnection of the HFEF/S air compressor. If there were a failure of the HFEF/N plant air system the HFEF/S compressor would provide air to the failed system. In the event of a failure of the normal electrical power in both HFEF/N and HFEF/S, both plant air systems would be inactive. Under these conditions, the instrument air compressor in HFEF/N would start. If the highly unlikely event that a normal and total emergency electrical power failure to both buildings, along with an instrument air system failure, happened simultaneously, the major systems would react in the following manner:

- The subassembly storage pit cooling blowers and purification blowers providing cooling to the fuel storage pits would shut down. (See Section IV.C.)

- The argon purification system would be inoperative with the compressors off and the valves closed on loss of instrument air. A solenoid valve would close on loss of electrical power shutting off the supply of hydrogen to the purification system. The loss of the purification system is not critical to the safety of the facility during the hypothetical loss of normal power, emergency power and instrument air.

- In both the refrigerated air supply system and the evaporative cooling air supply system, the valve to the preheat coils would fail open, thus preventing the coils from freezing. The fans would shut down and the dampers would fail closed, cutting off the air supply. The air supply systems would not operate if the instrument air and electrical power were lost. The loss of air supply systems would not affect the safety of the facility.

- The cell exhaust system fans would be inoperative and the shut-off dampers in the system would close. Any over-pressure buildup in the Main Cell would be relieved through the seal pot and relief stack. Any over-pressure buildup in the Decon Cell would relieve through the hot and suspect repair areas, which in turn could contaminate the high-bay area. The exhaust fans in the high-bay area are interlocked with the fans in the cell exhaust system so that if both cell exhaust fans fail, the high-bay fans shut off. A failure of the cell exhaust system, although highly improbable, would cause an evacuation of the facility until the system was again in operation and the facility was surveyed for any possible release of contamination from the Decon Cell or the hot repair area and suspect repair area to the high-bay area.

- A failure of the building exhaust system will not affect the safety of operations in the facility; however, personnel are instructed not to use laboratory hoods while the building exhaust is inoperative.

- The Decon Cell dampers would fail normally open, thus maintaining safe conditions in the cell.

- The valves on the wall fin-tube radiators fail normally closed and pose no safety problem.

- The three-way valves on the fan-coil units fail in the bypass position with no safety problem.

- The argon cooling system does not operate during a failure of normal electrical power or instrument air. The loss of the system does not cause a safety problem.

- The valves in front of the subassembly storage pit blowers fail normally closed (i.e., upon loss of instrument air) thus cutting off cooling to the subassembly storage pits. (See Section IV.C.)

14. Personnel Air System

The plant air system provides clean, dry, oil-free air to the personnel air system used in the repair areas above the cells and in the tunnel areas on the service floor.

A failure in the personnel air or plant air systems, or an electrical power failure could cause a safety hazard if, at the time, personnel were using breathing air in a contaminated area. An audible alarm signaling a drop in pressure is mounted near the work station to warn the personnel to leave the contaminated area.

15. Argon Supply System

Two liquid argon tanks (each containing an equivalent of approximately 170,000 ft³ of gas) supply argon to EBR-II, HFEF/S and HFEF/N. One tank at HFEF/N usually supplies HFEF/N but piping connects the tanks so both could be used. The gas moves through a surge tank to the argon-atmosphere normal supply system, which includes the subassembly cooling loop, the system dryer purge, the sensing line purge, the transfer lock fill, and the outlets in the laboratories. In addition to the normal supply system, there is a separate emergency argon supply contained in ten storage bottles on the service floor.

A failure of the argon supply systems, including the emergency supply, could affect the operations within the facility, but the possibility of a failure of both systems is remote. The HFEF/N system is essentially the

same as the HFEF/S system in the arrangement and types of piping and components. In ten years of operating experience in HFEF/S, there has never been a failure of the argon supply systems. If there were a failure in the system, low pressure in the argon supply system would be sensed and annunciated as part of the building equipment alarm system. Unless there were other problems associated with the containment in the Main Cell, the surge tank, and if necessary, the emergency argon supply should maintain normal operations until the malfunction is repaired. Bottles of argon gas are available from Aerojet Nuclear Company stock and could be on site within an hour. Tank truck loads of liquid argon can be delivered in one to two days from Salt Lake City, Utah.

16. Transfer-lock Vacuum System

Two vacuum pumps in parallel evacuate argon gas from the lock between the Main Cell and the Decon Cell, from the cask lock, and from the main equipment transfer lock. The evacuated gas is suspect and is discharged from the pumps to the building-laboratory suspect-exhaust system. A failure of the system would prevent the transferring of subassemblies, material and equipment in or out of the Main Cell. The system failure would affect the operations within the facility, but would not necessarily affect the facility safety. With two vacuum pumps in the system the reliability is high. Repairs to other components or piping should be straightforward assuring high availability of the system. Interlocks in the system prevent the vacuum pumps from evacuating argon gas from the Main Cell if the locks are not perfectly sealed. Controls in the Large Lock Transfer System prevent (a) venting the lock without hydraulic pressure adequate to support the ram, (b) lowering the ram until the lock has been vented to atmospheric pressure.

17. Normal Power Supply

Electrical power, fed either from the dual transmission lines (one on-the-line and one standby) of the Utah Power and Light Company or from the EBR-II power plant, is available for HFEF/N from a 750-kVA substation located south of the facility. Four underground feeders from the substation to the facility provide all of the normal power. One of the feeders energizes two bus ducts which carry the lighting loads and the in-cell electrical loads. Another feeder powers most of the building equipment located on the service floor. The third feeder is connected to most of the equipment loads associated with the argon cooling system. The fourth feeder supplies normal power to the emergency power circuit through an automatic transfer switch. All critical equipment and electrical components are connected to both the normal electrical power and the emergency power circuits. Loss of normal electrical power will stop operations in the facility. However, in the past five years, there have been only three power failures exterior to the ANL-West site that have lasted longer than three minutes. During this same five-year period there were twenty-four electrical

outages lasting less than three minutes which were mainly caused by lightning strikes on exterior transmission lines and substations. The power failure rate over a five-year period indicates a high degree of reliability and availability of the normal power sources.

18. Emergency Power System

A 200-kW diesel-generator located on the service floor supplies the emergency electrical power to critical equipment when there is a failure of the normal electrical power. An automatic transfer switch is actuated when a normal power failure occurs, switching from normal power to emergency power. Within seven seconds after the failure, the diesel-generator is started and picks up the emergency power load. The diesel-generator is tested and inspected every week as part of the preventive maintenance program. In its short operating life, the diesel-generator has started the first time in twenty-two weekly tests in an average of seven seconds. In an actual power outage, the unit started automatically with no abnormalities noted. A backup emergency electrical power (BEEP) system, consisting of a 60-kW diesel-engine driven generator, automatically supplies power to several highly essential loads if the 200-kW generator or transfer switch fail. Critical equipment connected to the 200- and 60-kW emergency power distribution systems are listed in Section I.B.5 of this report. Problem areas with individual pieces of critical equipment on emergency power are considered in the section covering their systems.

19. Communication and Alarm Systems

The telephone and paging system for HFEF/N is supplied from the L&O Building through an underground conduit to Pumphouse No. 1, and then to the southeast stairwell of HFEF/N. Telephones and public address systems are provided by Mountain Bell. The HFEF/N facility has telephone service and a public address system for normal and emergency communication. Emergency power for telephone service is provided by a battery system located in the L&O Building. The public address system is connected also to the emergency power system for operation in the event of a site power failure. By dialing 13, the caller alerts the security post, the fire department, key management personnel, Health and Safety, and the first aid office with one telephone call.

The evacuation alarm system has sirens located on all floors of the facility and has a control station located in the lobby of the main entrance. An evacuation or alert signal can be initiated manually at the control station or automatically activated by the radiation monitoring system. The evacuation alarm system is powered by both normal and emergency electrical power for added reliability. The public address system could be

used as a backup system to evacuate the facility, if necessary. The evacuation alarms are tested each week as part of the preventive maintenance program.

The HFEEF/N facility, with the exception of the Main Cell and Decon Cell, is protected by heat detectors and photoelectric detectors. In addition, automatic sprinklers are installed in the truck lock and the emergency generator room. Manual fire alarm boxes are also available to alert the local fire department of a fire. The alarms actuated are annunciated at an indicating unit in the operations control office, the operating floor, and the northwest stairwell. A total of sixteen stations or zones are annunciated. For increased reliability, the fire alarm system is powered by both normal and emergency electrical systems. A failure in the system could cause a safety problem, but the telephone system can be used as a backup by dialing 13. The fire alarm system is tested bimonthly and the sprinkler heads annually as part of the preventive maintenance program.

The facility is monitored for radiation of a predetermined activity by a stack monitor, area gamma monitors, area alpha air monitors and beta-gamma air monitors. Actuation of a radiation monitor will automatically trigger an intermittent evacuation alarm to be sounded. The alarm is annunciated in the operations control office, the Radiation Safety Section office or the EBR-II power plant. The radiation monitoring system is connected to normal and both emergency electrical supplies for added reliability. The radiation monitors are inspected and calibrated on set schedules unless they are observed to be inoperative in the routine surveillance by the Radiation Safety technicians. If inoperative, the monitors are replaced and repaired.

The building and process equipment alarms listed in Section I.B.10 of this report are automatically annunciated at the operations control office or the EBR-II power plant control room if an off-standard condition exists. These alarms are also powered by the normal and emergency electrical systems. The equipment operating characteristics monitored by this system are critical to the operations and safety of the facility. Continual evaluation and testing of all instruments are performed by the instrument group to determine the reliability of the individual instruments and circuits.

Certain critical temperatures are monitored and annunciated in the operations control office, the operating corridors, and the Radiation Safety office. The critical temperatures annunciated on the following equipment are:

- Main Cell argon blower bearing B-1-A--High temperature
- Main Cell argon blower bearing B-1-B--High temperature
- Subassembly pit blower bearing B-2-A--High temperature

- Subassembly pit blower bearing B-2-B--High temperature
- Purification cooler--High temperature
- Subassembly pit cooling--High temperature.

Electrical power is supplied from both normal and emergency sources.

The subassembly pit cooling system is critical and special consideration of the alarms and controls is worthy of mention. Normally, two pit cooling blowers each supply cooling gas to five of the ten in-cell subassembly storage pits. If one pit cooling blower fails, sensors detect a loss of flow and pressure, actuate an alarm on the annunciator panels and automatically divert gas flow from an argon purification blower to the subassembly cooling circuit. The subassembly cooling system includes pressure, temperature, and flow sensing instrumentation with alarms on abnormal flow in either cooling circuit, above normal blower motor bearing temperatures and above normal cooling gas temperature. Manual bypass valves permit connection of any of the four blowers (two pit cooling, two purification) to either or both subassembly cooling circuits. All four blowers are on the 200-kW and BEEP emergency power systems. (The pit cooling blowers are automatically switched to BEEP; the purification blowers are manually switched). One blower supplying ten pits will prevent meltdown though some loss of experimental data may be encountered.

20. Ventilation System

The ventilation system is comprised of five major subsystems: (1) the refrigerated air supply, (2) the evaporative-cooled air supply, (3) the building and laboratory exhaust, (4) the cell exhaust, and (5) the clean exhaust. Together the systems provide 100% filtered supply air to the facility to heat, cool and provide a ventilation flow pattern. The subsystems are designed so that air flows are from clean areas to suspect areas, then to known contaminated areas. The following are descriptions of the systems along with an analysis of their operations and safety:

(a) The refrigerated air supply distributes air-conditioned air to the offices and laboratories on the operating floor and the second floor. The system directs 33,600 cfm of outside air to the facility through a preheat coil, prefilter, final filter, cooling coil, two supply fans and fourteen reheat coils. The system uses two 50% capacity fans. One of the two fans will operate on emergency power during a failure of the normal electrical power. Either fan can be preselected as the one to operate during a power failure. The fan that is not preselected to remain in operation during an electrical power failure will also be automatically stopped in case one of the building-laboratory exhaust system fans is stopped or fails. In case both exhaust fans stop, both supply air fans stop automatically. The cooling coil in the supply air system will be drained in the wintertime to prevent freezing, although the steam valve on the preheat coil located upstream of the cooling coil fails open allowing steam to enter the coil and heat the air. Also, the supply fan shuts off if the air temperature in the plenum is too low.

(b) The evaporative-cooled air supply ventilates the service floor, the suspect exhaust room on the north side of the second floor, and the high-bay area. The air supply system includes a preheat coil, a prefilter, a final filter, a cooling coil, an air washer, and two supply air fans. Under normal conditions, both fans operate. During an electrical power failure only one (preselected) fan operates on emergency power. When the normal power supply is restored, the fan that had been stopped starts automatically. The valves to the steam preheat coils fail open on a loss of instrument air, thus preventing a possible freezeup of the coils during the winter. As in the case of the refrigerated air supply, if one of the two building-laboratory exhaust subsystem fans fail, one of the two supply fans shuts down (the preselected fan will continue to run).

(c) The building-laboratory exhaust subsystem removes the ventilation air from building spaces and equipment that are normally free of airborne radioactive contamination. For protection in case of an accidental release, however, all exhaust air is filtered through HEPA filters before being discharged to the atmosphere. The system includes two exhaust fans, each rated at 50% of capacity. If there is an electrical power failure, only one fan would operate on emergency power. As previously stated, the supply air systems are interlocked so that one of the supply fans shuts down if there is a failure of one of the exhaust fans. More detailed description of the building laboratory exhaust system appears in Section I.B.1.b of this report.

(d) The cell exhaust system removes air that is known to be contaminated from the Decon Cell, the cask tunnel, the vacuum pump discharge, the high-bay area, and the Main Cell normal exhaust. Two fans (and an installed spare) remove contaminated air from the facility through HEPA filters. A more detailed description of the system appears in Section I.B.1.c of this report.

(e) The clean exhaust system provides unfiltered exhaust from non-suspect (clean) areas of the building. Some clean areas are the toilet rooms, the high-bay area, the instrument laboratory, operations office, emergency generator room and truck lock.

(f) In order to have the five systems operate properly together and to have the air flow patterns in the building follow the design conditions, all doors, hatches, truck lock doors and other openings are kept closed when not in use. The areas known to be contaminated thus retain a negative pressure with respect to adjacent suspect or clean areas to prevent the spread of contamination. Periodic ventilation tests will be conducted to confirm that initial flow patterns are maintained.

(g) Failure of the refrigerated air supply could affect the operation, but should not affect the safety of the facility. Failure of one fan or

other components should be easily corrected by repairing or replacing the malfunctioning component. The loss of cooling in the summer, or heating in the winter, could affect the operations, but the conventional equipment should have high reliability and availability.

(h) Failure of the evaporative-cooled air supply could affect the operation, but not the safety of the facility.

(i) Failure of the building-laboratory exhaust system could affect the operation and the safety of the facility. When the two exhaust fans operate simultaneously, each provides 50% of system capacity: On the failure of one fan, the other provides 67% of system capacity. The annunciator system sounds an alarm and lights an indicator in the operations office if either fan fails or if there is off-standard plenum pressure. The butterfly valves shutting off the air flow to both fans will be tested on a routine maintenance schedule under nonstandard conditions to assure proper and reliable operation.

(j) Failure of the cell exhaust system would affect both the operations and safety of the facility. Under no circumstances will all three cell exhaust fans be out of service at the same time. One of the fans will maintain a safe building airflow pattern. The system maintains a negative pressure in the Decon Cell and in the Main Cell normal exhaust which prevents a potential spread of contamination from these areas to the rest of the facility. Two most probable causes of failure in the system would be: (1) a failure of the normal electrical power supply, and (2) a failure of the butterfly dampers downstream from both fans. If a failure of normal power occurs, the diesel-generator, from operating experience, provides power in eleven seconds and is highly reliable. (Also, one cell exhaust fan is supplied power by the 60-kW BEEP system.) The second probable cause of failure (the butterfly dampers fail to function properly) will be diminished by testing the dampers often under nonstandard operating conditions to ensure that they perform properly.

(k) Failure of the clean exhaust system, although a nuisance, would not affect the operation or the safety of the facility.

F. Earthquake and Tornado Evaluation

1. Earthquakes

At the time the HFEF/N was designed, the entire INEL was classed as a Zone 2, Uniform Building Code seismic area. Later, the Uniform Building Code (UBC) was revised with a revised Seismic Risk Map showing the INEL area to be in Seismic Zone 3. This change, in effect, increased the recognized UBC-required earthquake loads by a factor of 2.

Seismic criteria for the INEL area for nuclear engineering structures have not been clearly defined. Seismic Zone 2 is approximately equivalent to an earthquake design acceleration of 0.065 gravity applied to conventional building. Seismic Zone 3 is approximately equivalent to an earthquake design acceleration of 0.13 gravity applied to conventional buildings. The earthquake provisions of the Uniform Building Code reduce these implied accelerations to a series of design rules for equivalent static forces for use in building design.

In calculating stresses due to earthquake loads, Section 2303 of the Uniform Building Code was utilized by the design engineers. This section includes the statement that "All allowable stresses and soil-bearing values specified in this Code for working stress design may be increased one-third when considering wind or earthquake forces either acting alone or when combined with vertical loads." Thus, there is a smaller factor of safety against failure by yielding when the actual stresses experienced during an earthquake approach the calculated design stresses. This is considered acceptable based on the low probability of occurrence of a design-basis earthquake.

The design of a building structure includes many factors such as dead load, superimposed live load, wind load, earthquake load, impact due to suddenly applied loads, radiation protection, stability against buckling, and provision to avoid excessive flexibility or deflection. The size and the proportions of a structural member may thus be controlled by factors other than earthquake load.

In the HFEF/N analysis for earthquake loading, calculations show no case where the size of a member or proportions of a detail was controlled by a Seismic Zone 2 earthquake loading. The following are examples:

Structural calculations for lateral forces applied to the roof structure show Zone 2 seismic forces between 10 and 59% of calculated wind forces. Wind forces and earthquake forces are not considered as occurring simultaneously, and thus wind forces controlled the design.

Calculated shear stresses in the hot cell walls due to seismic loads are from 10 to 27% of the allowable shear stresses. Calculated stresses in slabs due to lateral seismic loads vary from 10 to 38% of allowable shear stresses. Calculated lateral loads on dowels for shear transferred by the dowels to or from the exterior hollow unit masonry walls is 65% of the allowable load.

Thus, on the basis of the UBC Seismic Zone 2 criteria and calculations, the building structure of HFEF/N provides adequate resistance against earthquake loads contemplated by Seismic Zone 2 requirements.

In evaluating the strength of HFEF/N against Seismic Zone 3 requirements, the earthquake stresses of some elements come closer to approaching the allowable design stresses. Judging the HFEF/N building design against the action of other similarly designed buildings of a conventional nature in earthquakes of the same magnitude anticipated by the rules of the UBC, some minor amount of structural damage may be expected in the case of an earthquake of the magnitude corresponding to Seismic Zone 3.

An additional element has been included in the HFEF/N cell design that would assist in controlling release of nuclear materials. The cells contain a 1/4-inch steel-plate liner that should have enough flexibility to provide containment in the unlikely event of cracking of the concrete during a severe earthquake.

It is concluded that the HFEF/N structure should be adequate to resist an infrequent earthquake with motion equivalent to Modified Mercalli VI with an acceptable level of damage.

2. Tornados

The following wind loads were used in the design of HFEF/N: "The total wind pressure to be applied to the structure shall be as follows:

30 lb/sq ft from grade to 30 ft above grade

35 lb/sq ft from 30 to 50 ft above grade

40 lb/sq ft from 50 to 75 ft above grade

45 lb/sq ft from 75 to 100 ft above grade

"Of the above total wind pressure $61\frac{1}{2}\%$ shall be applied to the windward side and $38\frac{1}{2}\%$ shall be applied to the leeward side of the structure simultaneously."

With these loads an increase in working stress was utilized in accordance with Section 2303 of the Uniform Building Code: "All allowable stresses and soil bearing values specified in this Code for working stress design may be increased one-third when considering wind or earthquake forces either acting alone or when combined with vertical loads..." When adjustment is made for 5000-ft altitude, at a temperature of 30°F, the wind pressure of 30 psf is equivalent to a gust velocity of approximately 100 miles per hour.

The structural members in HFEF/N were designed to the specified wind loads, utilizing the increase in allowable stress permitted by the Uniform Building Code and the adjustment permitted for windward and leeward sides of the building.

There have been several criteria considered for design to resist tornados based on midwestern tornados. Wind velocities of 170 to 300 mph have been proposed, accompanied by a severe drop in atmospheric pressure and by flying missiles. A wind velocity of 170 mph would be equivalent to a static load of about 85 psf (not divided between the windward and leeward sides of the building). The design of HFEF/N structural members, roofing, or siding did not consider wind loads of this magnitude.

Further, it is considered that the wind-load design criteria used for the design of HFEF/N is justified and acceptable for the following reasons. Idaho has one of the lowest frequencies of reported tornados of any state in the United States. For example, in 1971 when 890 tornados were reported in the United States, none were reported in Idaho. Further, in 22 years of observations at the INEL, only two funnel clouds have been confirmed and no tornados have been reported. There may also be a difference in intensity of tornados reported in Idaho and those in a typical midwestern or southern state. A survey of tornados reported in Idaho in the past 24 years indicates they were circular winds of relatively low velocity, but where damage has resulted, the damage has been of a nature that would indicate circular winds not exceeding 100 miles per hour.

The HFEF/N structure has, in effect, been tested under near-tornado conditions and found to be adequate. On January 11, 1972, there was an extreme wind condition with a measured gust velocity of 82 mph at the 150-ft level of the wind tower approximately 1000 ft southeast of HFEF/N. This velocity of 82 mph, when reduced to the 85-ft ridge height of HFEF/N, by the usual $1/7$ -power rule for relation of wind velocity to height above ground, would have been 76 mph. Under this wind condition about 3000 ft² of roofing was destroyed. No distress of the structural members was evident.

On the basis of design, and on the basis of actual experience, it is concluded that the structure is adequate to resist infrequent storms with winds up to 100 mph with an acceptable level of damage to the shell of the building. However, the cell structures should not suffer damage even in winds considerably in excess of 100 mph.

SECTION IV
EVALUATIONS OF POTENTIAL ACCIDENTS

IV. EVALUATIONS OF POTENTIAL ACCIDENTS

A. Criticality Accident

The fuels of greatest interest to the LMFBR Program which will be handled in HFEF/N are the oxides of uranium and plutonium. Although fully-enriched uranium and pure plutonium may be examined on an experimental basis, the amount of such fuels will constitute only a small fraction (<10%) of the facility workload. The following discussion of the possibility of a criticality accident in either of the two cells is based largely on partially-enriched fuel, and represents the typical situations that are most likely to occur in the facility. The contributions of fully enriched fuel to potential criticality hazards do not change the arguments because of the small amounts of these materials which will be present. Although the arguments given below cite uranium as an illustration, they also hold for plutonium for which the working limits are established at one-fourth those for ^{235}U . The arguments for the criticality safety of ^{235}U , as given in the illustrations, are therefore applicable to the equivalent quantities of plutonium.

In the Criticality Statements for HFEF/N, summarized in Section III.A, rules and procedures are set up to avoid the accumulation of fissile material in amounts that might go critical. These critical amounts are based on the pessimistic assumptions of efficient reflection, specialized geometry, and freedom from poisoning impurities. For example, 23 kg of ^{235}U metal is required to go critical in a sphere, fully reflected with water. The limits for zones where undiluted metallic ^{235}U fuel is handled are set at 10 kg or less. Therefore, even for fuel in spherical form, the zone limits for handling fissile materials incorporate a safety factor of at least 2.3, but with the fuel in pin geometry, either in a subassembly or not, the safety factor is much larger. The EBR-II dry critical experiment, for example, with 48% enriched pins in hexagonal subassemblies, required about 200 kg ^{235}U for criticality. This suggests that a safety factor of at least 20 has been incorporated in the zone limits as far as any rearrangement of pins in subassemblies is concerned.

In the Criticality Statements, no mechanism is necessarily postulated to explain the process of rearrangement of the fuel from its pin/subassembly geometry (safety factor of at least 20), to the specialized case of a reflected sphere (safety factor of 2.3). In fact, with the possible exception of a meltdown, there is no conceivable way in which the fuel, in pin geometry, can be transformed into anything similar to a sphere. In the absence of such a mechanism, the zone limits must be considered as allowing a safety factor of between 2.3 and 20. It is postulated to be credible that the fissile material in a zone could be double-batched accidentally, in the course of moving from zone-to-zone, or in some other unforeseen way. It is not regarded as credible, however, that any amount significantly

greater than a double-batch, would ever be accumulated accidentally in any zone. This would still leave a factor of at least ten for the safety of any credible collection of fuel elements. With such a high safety factor, the accumulation of a critical configuration of fuel elements is not regarded to be credible.

The meltdown situation must be considered separately, however. Decay heat in an uncooled irradiated subassembly could conceivably produce fuel melting, or at least such melting of the support structure as to permit the fuel to collapse into a more condensed form. A single subassembly, however, limited to 6 kg of ^{235}U for EBR-II, or possibly as much as 10 kg of ^{235}U for other systems, does not have sufficient fuel for criticality. The Main Cell storage pits are permitted to contain up to 4 subassemblies (not to exceed 18 kg ^{235}U) per pit. Even this is less than the minimum critical mass for a sphere fully reflected by water. A physical limitation prevents more than 4 subassemblies from being loaded into a single pit. If the pits were wrongly loaded, however, with 4 subassemblies containing 6 to 10 kg each, the mass per pit, 24 to 40 kg ^{235}U , would be sufficient that in the event of a meltdown, a roughly spherical residue might be in the range of criticality. The possibility of a meltdown of an accidentally overloaded storage pit should therefore be examined.

First, it should be noted that the overload itself would not necessarily lead to a meltdown situation. Each subassembly in the pits is cooled by 30 cfm of argon, and the collection of 4 subassemblies (120 cfm), would not reach substantially higher temperature than a single subassembly with 30 cfm. Furthermore, this is the same flow rate that cools the subassemblies in the Interbuilding Coffin (IBC) and if they did not melt in their journey to HFEF/N in the IBC, they would not melt under the same cooling conditions in the pits. Consequently, the overloading of the pit and the subsequent meltdown, are two separate and independent contingencies. It is generally regarded in criticality analyses that an accident is incredible if two reasonably remote and independent contingencies must occur simultaneously in order to produce that accident.

The first contingency in the above sequence is made reasonably remote by the administrative controls on the loading of the storage pits. The second contingency, the meltdown itself, would require the loss of coolant flow, and the probability of this happening is reduced to a very low degree by the multiplicity of the available blowers and power supplies. There are four blowers available with automatic and manual switching in case of failure of an operating fan. There are two diesel emergency power supplies that switch on automatically in case of line power failure. One blower supplying ten pits will prevent meltdown though some loss of

experimental data may be encountered. Thus, complete loss of coolant is a very unlikely contingency itself, and could only happen in the event of complete loss of all power sources plus some duct failure. To couple this with the chance of a loading error would reduce the possibility of the sequence to the incredible range.

Finally, the meltdown of subassemblies in adjacent pits, each loaded with 18 kg ^{235}U , is considered. Since these are separated by two feet, the resultant masses, even if nearly spherical, would not be close enough for critical interaction.

In summary, there is no credible accident by which the pin geometries could become critical because of the extremely large safety margin on mass in this geometry, and there is no credible mechanism by which melting into some near-spherical geometry could produce a critical configuration.

The above arguments apply in moderator-limited (essentially dry) areas where fissile material is limited to 10 kg ^{235}U or equivalent, but they also apply equally well to moderator-unlimited areas where fissile material is correspondingly limited to less than half of an optimally moderated and reflected spherical critical mass. Thus, they cover all the regions of operation in the Main Cell, Decon Cell, or out-of-cell areas in HFEF/N. The Decon Cell has been proposed for use with either the dry or moderated fissile limits depending on whether the spray chamber is in operation or not. It is anticipated that in the future, dry limits may be applied in the dry areas of the cell concurrently with moderated limits in the spray area while spraying operations are in progress. This will not be permitted, however, unless experience and analysis have convincingly demonstrated that the water in the spray chamber can be completely contained therein. Thus, the criticality arguments given above for the dry and moderated areas are not invalidated by any possibility of moderator accidentally entering a supposedly dry region.

B. Sodium Fire

In considering the circumstances that could lead to a sodium fire, one should note that during operations involving the handling of sodium in either the Main or Decon Cell, water or other chemicals that react with the sodium will be restricted to safe quantities. Further, the operations covered by this report do not include any that could credibly result in a spray of sodium. Hence, consideration will be given to the probability and consequences of a sodium pool fire only.

Operations within the Main Cell involving sodium include the destructive examination of sodium-bonded elements or capsules and the storage of multigallon quantities of sodium from the examination of loops. The Sodium Loop Safety Facility examination operations will be covered in a supplementary report.

The destructive examination of elements and capsules will expose less than one pound of sodium at one time. The sodium from loops will be transferred and handled within a closed piping system within the cell. However, during disassembly of the loop, the surface of the contained sodium is exposed to the cell atmosphere through the open top (about 10 in.²) for about a day before the sodium is removed. If the oxygen content of the cell atmosphere should rise significantly, the interior of the loop will be purged with pure argon to maintain an inert cover gas. The exposed sodium on the surfaces of the loop components during disassembly is expected to be less than one pound. Hence, the total sodium in the Main Cell exposed for more than a brief period will be less than two pounds.

The Main Cell contains argon gas with 50 ppm or less, each of oxygen and water vapor. Since sodium will not burn in an atmosphere containing less than 4 volume percent oxygen, there is a considerable margin of safety. It would require a major occurrence of extremely low probability to increase the oxygen content of the Main Cell to this level. Nevertheless, assume that the Main Cell atmosphere exceeds the minimum oxygen content for a sodium fire after a major occurrence, and that a fire is started in some manner. The consequences of a fire would be controlled within limits as indicated in the following paragraphs.

- Sodium from sodium-bonded elements or loop experiments tested to failure would contain principally radioiodine. The release of this activity would be below the guidelines of 10 CFR 100 (see Section IV.C).
- The release of sodium oxide aerosols would not block either the normal exhaust filters nor the filters for gas recirculation and emergency exhaust. The sodium fire abatement tests conducted at EBR-II,¹ indicated that a 1000-cfm capacity HEPA filter could retain 4 pounds of sodium oxide vapor with a drop in flow of about 60%. Measurements on the fraction of sodium oxide released from a pool fire have varied from a few percent up to a maximum of 40 percent.² Assuming the higher release value, the two normal exhaust filters in the Main Cell could contain the 8 pounds of vapor which would be the maximum collected from 20 lb of burned sodium, or 10 times the amount of sodium exposed in the Main Cell.
- It is not credible that a small sodium pool fire could reach a sufficiently high temperature to propagate to nearby fuel capsules. For an uninsulated burning surface, the sodium surface temperature

has been reported at 1100 to 1250°F.³ Some of the fueled experiments in the reactor run at these temperatures. The flame temperature, a few inches above the pool, has been measured as high as 1800°F.² However, this small high-temperature region should not propagate the fire to other capsules.

Sodium would not normally be exposed in the air-atmosphere Decon Cell. A handling accident could result in the breaching of a sodium-filled container. The largest amount handled at one time would probably be a shipping container of 1 to 3 gal (8 to 24 lb) size.* The Decon Cell would be dry at the time a transfer was made and the spray chamber would be secured, thus eliminating the possibility of a sodium-water reaction. Also, the Decon Cell floor and lower walls are covered with steel plate so a concrete-sodium reaction could not occur. The sodium would not be transferred until the sodium had cooled to near cell temperature (less than 150°F). If a container were dropped and sodium exposed to the air, the sodium would not burn since this temperature is below the minimum autoignition temperature in air (approximately 245°F).⁴

If by some unforeseen circumstance the sodium should ignite, the heat released would not pressurize the Decon Cell. A typical burning rate for a pool fire is 0.5 lb/hr-ft²-%O₂** or 8.7 lb/hr-ft² at 5000 ft altitude. Assuming about 50% formation of Na₂O, the heat release is 1.32 kW-hr/lb. Hence, for a spill of 20 lb of sodium covering 8 ft² to a depth of one-half inch, the heat release rate would be about 92 kW for a period of 17 min. The maximum heat release rate in the cell from lights and equipment normally is about 20 kW. This is calculated to give a temperature rise of about 25°F with the normal exhaust rate of 3000 cfm. Since there are three exhaust filters, the exhaust rate is expected to be at least 1500 cfm following the fire. With no allowance for heat transfer to the walls, the cell air temperature is estimated to rise a maximum of 175 to 270°F. The temperature rises about linearly at a rate of 10°F/min which results in an average expansion of cell atmosphere of about 250 cfm which is well within the system capacity at the end of the fire.

It has been shown above, that it is highly improbable that a sodium fire would occur in either the Main or Decon Cells. However, if it did, the fire would not propagate and would be controlled within safe limits.

*Containers with up to 30 gallon sodium capacity may be handled in the Decon Cell following analyses which would show that the containers would maintain their structural integrity following a drop or other handling accident.

**"Applied Sodium Technology Training Course," Section VIII, Atomics International, 1974.

C. Results of Failures of Containment Barriers

It is reasonable to postulate that any single system or device, or any combination thereof (including administrative procedures), may fail in the operation of HFEF/N thereby possibly releasing activity to the environment. However, rather than attempt the complex analysis of each failure or combination thereof, the approach adopted herein is to analyze classes of failures which cover all possible release accident situations.

The HFEF/N facility has three containment barriers to prevent the release of radioactive materials:

1. The Main Cell, including the argon ventilation system.
2. The building containment structure, including the building ventilation system.
3. The fuel cladding. This is of particular importance for fuel stored in the cooling pits because of the possibility of meltdown under certain conditions if the storage pit cooling is lost.

All postulated accident conditions that might release activity must involve the failure of one or more of these barriers. Therefore, if all possible combinations (of which there are eight) of the availability or nonavailability of these barriers are analyzed, then all possible release accidents are automatically included. Evaluation of the conditions associated with failure of any combination of these barriers, and analyses of the consequences, are presented in this section.

It should be noted that the possible release accidents associated with HFEF/N are likely to be less severe than those associated with reactors for any or all of the following reasons. The fuel subassemblies and experimental capsules to be examined in this facility will be cooled for at least 15 days; therefore, the short-lived fission products will have decayed away. The possibility of a criticality accident with a resulting pressure pulse has been shown to be incredible (see Section IV.A); therefore, there is no driving force to inject fission products into the atmosphere. A sodium fire, which might provide a milder driving force, is thought to be essentially incredible; nevertheless, should it occur, release of activity from either the Main Cell or Decon Cell would be no worse than the situation arising from Case I (see below). Lastly, even under the incredible circumstances leading to the loss of all three containment barriers simultaneously, although the noble gases and iodines are assumed to be released immediately, it would take at least an hour before meltdown of the subassemblies in the storage pits with consequent release of solid fission products; there would thus be a period of time during which some corrective action could be taken to minimize the consequences.

1. Possible Combinations of Failures

With three containment barriers and the possibility of losing one or more of them, eight possible combinations result: the loss of no barrier; three combinations involving the loss of one; three combinations involving the loss of two; and, the extreme case of losing all three.

In carrying out the analyses, the commonly accepted "recipe"⁵ was used whereby 100% of noble gases, 25% of iodines, and 1% of particulates were considered available for escape to the atmosphere. However, in Case VIII, only 0.05% of the plutonium particulates were considered available because of the confining geometry of the storage pit and the absence of combustible materials.⁹ Also, in Case VI, 100% of the fuel dust* was arbitrarily considered available.

In normal operation of the Main Cell, quantities of the noble gases, iodines and particulates will accumulate. This is taken to be the equivalent of four subassemblies of ⁸⁵Kr (223 curies); one subassembly of ¹³³Xe (6537 curies); one pin of ¹³¹I (140 curies); one pin of ¹³²I (28.3 curies); and one gram of fuel dust containing 0.25 grams of Pu and its associated fission products after a decay time of 15 days.

The typical fuel composition of the individual pins consists of 25 w/o of oxide of plutonium, 68 w/o oxide of ²³⁵U and 7 w/o oxide of ²³⁸U. Isotopes of plutonium are distributed by weight typically as follows: ²³⁸Pu--0.03%; ²³⁹Pu--88.4%; ²⁴⁰Pu--10.4%; ²⁴¹Pu--1.3%; and ²⁴²Pu--0.04%. Only ²⁴¹Pu behaves differently in the body from the other isotopes; however, since only 1.3% of ²⁴¹Pu is present, the plutonium content was treated as if it were all ²³⁹Pu. The fuel section of a pin is 13.5 inches long and contains up to 17.8 grams of plutonium. It is encased in a stainless steel cylindrical jacket, and is typically 40 to 60 inches long and 1/4 to 3/8 inch diameter. A fuel subassembly typically consists of 37 jacketed pins. A total of 33 subassemblies contained in the Main Cell and the cooling pits was assumed in performing these analyses.

In considering the total inventory of gaseous activity potentially available for release from the cell, the following assumptions were used. Not more than two subassemblies per day can be received from EBR-II. These will be, at the earliest, from the last reactor shutdown and would have been cooled at least 15 days before transfer. Taking into consideration the half-life of ¹³³Xe (5.3 days), ¹³²I with its parent ¹³²Te (3.2 days), and ¹³¹I (8.05 days), it can be shown that the effective numbers of 15-day cooled

*The maximum quantity of fuel dust considered to be available was arrived at by estimating, on the basis of actual measurements, the total amount of such dust in the Argon Cell of HFEF/S.

subassembly equivalents (SA-equiv in the tables) are 7, 5 and 10, respectively. In addition, the maximum ^{85}Kr inventory will be that associated with 37 subassemblies, of which 32 are in the storage pits, one is undergoing examination in the Main Cell, plus the quantity of ^{85}Kr circulating in the cell gas at equilibrium which is assumed to be that from 4 subassemblies. This is based on the arbitrary assumption that the equivalent of four failed fuel assemblies may be processed per year. Thus, for any loss of cell containment, those gases already in the gas phase may be lost; for loss of cell containment accompanied by meltdown in the storage pits, the gas inventory plus certain subassembly-equivalents may be lost as shown below:

	<u>Gas Inventory</u>	<u>Cell Inventory</u>	<u>Total</u>
^{85}Kr	4 SA-equiv	33 SA-equiv	37 SA-equiv
^{133}Xe	1 SA-equiv	7 SA-equiv	8 SA-equiv
^{131}I	1 pin-equiv*	10 SA-equiv	10 SA-equiv + 1 pin
^{132}I	1 pin-equiv*	5 SA-equiv	5 SA-equiv + 1 pin

The value of a maximum of 33 SA in the cell is based on having 8 of the ten pits completely filled with subassemblies (for a total of 32), plus one subassembly (which may be failed) being examined in the cell. The other two storage pits are assumed to be filled with waste or other noncontributing materials.

A summary of conditions in the HFEF/N facility during each of the eight possible accident conditions is presented in Table IV.1. Table IV.2 shows the amounts of activity contributed by the noble gases, iodines, and particulates for each of the accident types. Wherever a "yes" for a given containment barrier occurs in Tables IV.1 and IV.2, full advantage is taken of its operation, i.e., failures of the remaining barriers are such as to allow maximum function of those in working order.

It should be noted that Case I, in which all containment barriers are available, represents normal operation. However, it also covers the case where a capsule dropped in the Decon Cell could rupture and release its iodines and noble gases which could escape through the normal cell exhaust system. Thus, this condition is presented in Table IV.2 and the small doses which might result are presented in Tables IV.4 and IV.5.

2. Calculated Radiation Doses

A summary of the numbers of curies of fission products in one pin, one subassembly, and 33 subassemblies, and also the numbers of curies of

*The concentration of ^{131}I and ^{132}I corresponds to that of 1 fuel pin equivalent since the argon circulation system handles 18000 cubic feet per minute of which 16% passes through the iodine-absorbing charcoal filters. Iodines therefore do not accumulate in the cell. A one pin equivalent would be present if an accident were to occur just after the capsule was opened.

TABLE IV.1 (Contd.)

Case V (Contd.)

About 9500 cu ft of cell argon containing iodines and noble gases escape in the first two hours. This represents 14.4% of the cell volume.

5. An additional 10% of the iodines and noble gases is assumed to be vented in the 30-day period, or fraction thereof, following the event. Of this amount, about one-half is vented because of cell "breathing" due to atmospheric pressure changes and the other half because of continued expansion of the cell atmosphere due to decay heat.

Case VI

Main Cell Containment No
Building Containment No
Pit Cooling Yes

1. All normal filtration is gone.
2. One gram of fuel in the form of dust in the Main Cell escapes. This gram of fuel contains 0.25 gram of plutonium and a proportionate amount of fission products.
3. The amount of iodines and noble gases contained in the cell gas inventory can escape.
4. Pit cooling blowers are in operation.

Case VII

Main Cell Containment Yes
Building Containment No
Pit Cooling Yes

1. The building containment has been destroyed. This could happen as a result of a severe meteorological event such as a tornado or extremely severe thunderstorm.
2. Venting of 10% of Main Cell inventory of iodines and noble gases due to extreme atmospheric pressure drop of 3 in. of mercury.
3. In this case, Type C meteorological stability conditions would apply with wind speeds of 15-30 meters per second. The resulting doses would be 2 to 3 orders of magnitude lower than calculated under Type F conditions. The dose values shown in Tables IV.4 and IV.5 represent an extreme upper limit resulting from cell venting and dispersion due to Type F conditions.

Case VIII

Main Cell Containment No
Building Containment No
Pit Cooling No

1. Main Cell and building are breached.
2. All filtration is gone.
3. All power is off.
4. Decay heat causes fuel subassemblies to melt releasing fission products.
5. All fission products are uniformly mixed in the Main Cell.
6. Main Cell atmosphere heats up in first two hours to cause venting of 11% to the environment.
7. In first two hours 11% of the available noble gases and iodines are released (100% of the noble gases and 25% of the iodines are available).**
8. An additional 10% of the cell atmosphere is assumed to be released in the 30-day period or fraction thereof, following the event.
9. Fission products and plutonium begin escaping at the beginning of the second hour.
10. Only 1% of the fission products are available for release.
11. Only 0.05% of the plutonium is available for release.⁹ This is a conservative estimate since the figure of 0.05% applies to metallic plutonium under combustion conditions. In these fuel elements, the plutonium is in the form of PuO₂.
12. Since 11% of the cell atmosphere is vented in the first two hours and the particulates do not become available until the second hour, only some 5-6% of the particulates available for release are vented.[†]
13. An additional approximately 10% of the particulates is assumed to be vented in the 30-day period, or fraction thereof, immediately following the event.
14. Approximately 10% of the cell gases and particulates are lost after the critical 2-hour period following the incident. Of this amount, about one-half is vented because of cell "breathing" arising from atmospheric pressure changes and the other half from continued expansion of the cell atmosphere due to decay heat.

[†](Note: This case assumes the SA cladding integrity fails immediately. Consequently, the exposure from noble gases and iodines is taken for the two hours stipulated in 10 CFR 100. However, analysis indicates the temperature of the SA would not reach adequate level to melt the cladding and vaporize significant quantities of solid fission products and plutonium for at least one hour.)

**This is a lower venting rate than Cases III, IV, and V because emergency power, as well as normal power, has been lost.

TABLE IV.2. Availability of Radionuclides (curies) for Escape to Atmosphere for Loss of One or More Containment Barriers

	Accident Case							
	I	II	III	IV	V	VI	VII	VIII
Main Cell Containment	Yes	No	Yes	Yes	No	No	Yes	No
Building Containment	Yes	Yes	No	Yes	Yes	No	No	No
Pit Cooling	Yes	Yes	No	No	No	Yes	Yes	No
^{85}Kr	1.5 1 pin-equiv	2.22(2) 4 SA-equiv	2.06(3) 37 SA-equiv	2.06(3) 37 SA-equiv	2.06(3) 37 SA-equiv	2.22(2) 4 SA-equiv	22.2 4 SA-equiv x 10%	2.06(3) 37 SA-equiv
^{133}Xe	1.77(2) 1 pin-equiv	6.54(3) 1 SA-equiv	5.25(4) 8 SA-equiv	5.25(4) 8 SA-equiv	5.25(4) 8 SA-equiv	6.54(3) 1 SA-equiv	6.54(2) 1 SA-equiv x 10%	5.25(4) 8 SA-equiv
^{131}I	35 1 pin x 25%	35 1 pin x 25%	1.30(4) 10 SA-equiv x 25%	1.30(4) 10 SA-equiv x 25%	1.30(4) 10 SA-equiv x 25%	35 1 pin x 25%	3.5 1 pin x 25% x 10%	1.30(4) 10 SA-equiv x 25%
^{132}I	7.1 1 pin x 25%	7.1 1 pin x 25%	1.32(3) 5 SA-equiv x 25%	1.32(3) 5 SA-equiv x 25%	1.32(3) 5 SA-equiv x 25%	7.1 1 pin x 25%	0.7 1 pin x 25% x 10%	1.32(3) 5 SA-equiv x 25%
^{239}Pu	None	None	None	None	None	0.016 Ci (0.25 g)	None	0.698 Ci 11.1 gr ^a
Fission Product Particulates	None	None	None	None	None	Assoc. with 1 g fuel	None	1% of 33 SA
Comments	Damage to one capsule in Decon Cell	Main Cell filters remain intact	Breathing rate of Main Cell 14.4% in 1st 2 hr	Breathing rate of Main Cell 14.4% in 1st 2 hr	Breathing rate of Main Cell 14.4% in 1st 2 hr	All filtration lost	Sharp pressure drop ~3.0 in. mercury ^b	Breathing rate for gases and iodine: 11% in 1st 2 hr. Breathing rate for Pu and fission products: 5.5% in 1st 2 hr.

Note: Numbers in parentheses refer to powers of ten, for example $2.7(-3) = 2.7 \times 10^{-3}$, or $3.82(4) = 3.82 \times 10^4$.
 For activity in curies of the iodines or noble gases associated with individual pins or subassemblies, see Table IV.3.
 1 SA-equiv = 1 subassembly-equivalent.

^a0.05% of 33 SA + 0.25 g.

^b10% of Main Cell atmosphere vented through filters.

plutonium is presented in Table IV.3. The fission product inventory for a typical mixed oxide subassembly was calculated using the RIBD code⁶ for a time of 15 days after reactor shutdown. For fission products with half-lives less than 100 days it was assumed that the activities would be near the equilibrium value for subassemblies operating at 600 kW (corresponding to an average linear power of 14.4 kW per foot of fuel pin length).

For fission products with half-lives over 100 days, the activities were based on an average burnup of 7% (uranium and plutonium fission only). Assuming that the subassemblies were under full power only 50% of the time, the fission product activities are based on an average power of 300 kW for 552 days, or 166 megawatt days. (The uranium was assumed to be 90% enriched.)

Inhalation doses to selected critical body organs as well as to the total body were computed for the following two sets of conditions immediately following each of the accidents indicated in Tables IV.1 and IV.2: (1) the 2-hr dose for persons at the site boundary 5000 meters from the HFEF/N facility; and, (2) the 30-day dose at Mud Lake 35,000 meters from the facility. Doses due to direct submersion in a nominally semi-infinite cloud passing overhead and the direct gamma radiation from the radionuclides in the HFEF/N facility were also evaluated. Even though the attenuation of the containment barriers was neglected, the dose levels at the site boundary arising from direct gamma radiation were infinitesimal. At 300 meters the direct gamma radiation dose is calculated to be no more than 14 R per hour, assuming about 6.6×10^6 curies of mixed fission products (excluding the rare gases and iodines) inside the Main Cell, but neglecting the attenuation due to the cell wall. Local emergency relocation procedures would be fast enough to prevent any significant exposures to on-site personnel.

The calculations of the doses both at the site boundary and at Mud Lake are presented in Tables IV.4 and IV.5. A detailed analysis for Case VIII is given in Table IV.6. The techniques used to calculate the inhalation and submersion dose to the critical organs indicated in these tables are discussed in Appendix B. It is apparent from an examination of the doses received that they are appreciably lower than those indicated as guidelines in 10 CFR 100,⁷ both at the site boundary and at Mud Lake.

The 10 CFR 100 guidelines define an exclusion area which, in this case, may be taken as the INEL site as, "... of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure."

Further, it defines a low population zone (in this case taken as the area up to Mud Lake) as "... of such size that an individual located at any

TABLE IV.3. Fission Product Inventory (curies) in HFEF/N (15-day cooling time)

Isotope	Half-life ^a	In One Pin	In One Subassembly (37 pins)	In 33 Subassemblies
⁸⁵ Kr	<u>10.6 y</u>	1.51	55.7	1.84(3)
⁸⁹ Sr	52.0 d	3.57(2)	1.32(4)	4.36(5)
⁹⁰ Sr	<u>27.9 y</u>	10.6	3.95(2)	1.30(4)
⁹⁰ Y	64.1 h	10.6	3.95(2)	1.30(4)
⁹¹ Y	59.0 d	4.78(2)	1.77(4)	5.84(5)
⁹⁵ Zr	65.0 d	6.62(2)	2.45(4)	8.09(5)
⁹⁵ Nb	35.0 d	7.73(2)	2.86(4)	9.44(5)
⁹⁹ Mo	2.8 d	21.3	7.90(2)	2.61(4)
⁹⁹ Tc ^b	6.0 h	21.3	7.90(2)	2.61(4)
¹⁰³ Ru	39.6 d	5.89(2)	2.18(4)	7.19(5)
¹⁰⁶ Ru	<u>1.0 y</u>	99.3	3.68(3)	1.21(5)
¹⁰³ Rh ^b	57.0 m	5.89(2)	2.18(4)	7.19(5)
¹⁰⁶ Rh	30.0 s	99.3	3.68(3)	1.21(5)
¹¹¹ Ag	7.5 d	8.46	3.13(2)	1.03(4)
¹²⁵ Sb	<u>2.7 y</u>	3.35	1.24(2)	4.09(3)
¹²⁷ Te ^b	<u>109.0 d</u>	4.89	1.81(2)	5.97(3)
¹²⁷ Te	9.4 h	14.0	5.17(2)	1.71(4)
¹³² Te	78.0 h	27.6	1.02(3)	3.37(4)
¹³¹ I	8.0 d	1.4(2)	5.17(3)	1.71(5)
¹³² I	2.3 h	28.3	1.05(3)	3.46(4)
¹³³ Xe	5.3 d	1.77(2)	6.54(3)	2.16(5)
¹³⁴ Cs	<u>2.1 y</u>	2.54	94.0	3.10(3)
¹³⁶ Cs	13.0 d	29.1	1.08(3)	3.55(4)
¹³⁷ Cs	<u>30.1 y</u>	2.54	5.76(2)	1.90(4)
¹⁴⁰ Ba	12.8 d	3.68(2)	1.36(4)	4.49(5)
¹⁴⁰ La	40.1 h	4.41(2)	1.63(4)	5.39(5)
¹⁴¹ Ce	33.0 d	6.26(2)	2.35(4)	7.64(5)
¹⁴⁴ Ce	<u>284.0 d</u>	2.40(2)	8.89(3)	2.93(5)
¹⁴³ Pr	13.8 d	3.68(2)	1.36(4)	4.49(5)
¹⁴⁴ Pr	17.0 m	2.40(2)	8.89(3)	2.93(5)
¹⁴⁷ Nd	11.1 d	1.29(2)	4.67(3)	1.57(5)
¹⁴⁷ Pm	<u>2.6 y</u>	50.8	1.88(3)	6.20(4)
¹⁵⁵ Eu	<u>1.7 y</u>	4.35	1.61(2)	5.31(3)
¹⁵⁶ Eu	15.0 d	7.19	2.66(2)	8.78(3)
²³⁸⁻²⁴² Pu	--	1.11 Ci	41.0 Ci	1.35(3) Ci
		17.8 gr	6.57(2) gr	2.17(4) gr

Note: The numbers in parentheses refer to powers of ten, e.g., 2.41(2) = 241 = 2.41×10^2 .

^aHalf-lives longer than 100 days are underlined.

^bIsomeric state.

TABLE IV.4. Infinite Time^a Dose to Body Organs of Persons at Site Boundary for Two Hours after HFEF/N Accident of Indicated Type

	Type of Accident							
	I	II	III	IV	V	VI ^b	VII ^c	VIII
<u>Inhalation Dose, rem</u>								
<u>Body Organ</u>								
Bone	0.0	0.0	0.0	0.0	0.0	1.64	0.0	13.04
Whole body	1.28(-3)	1.28(-3)	0.068	0.068	0.068	0.045	1.28(-4)	0.613
Kidney	0.0	0.0	0.0	0.0	0.0	0.167	0.0	1.29
Lung (Sol)	0.0	0.0	0.0	0.0	0.0	3.55(-5)	0.0	1.69(-3)
Liver	0.0	0.0	0.0	0.0	0.0	0.220	0.0	1.82
Thyroid	0.72	0.72	38.2 ^d	38.2 ^d	38.2 ^d	0.72	0.07	29.26 ^d
Percent of 10 CFR 100 guide- lines (300 rem) for thyroid	0.24	0.24	12.7	12.7	12.7	0.24	0.02	9.8
<u>Whole Body Submersion Dose, rem</u>								
<u>Isotope</u>								
⁸⁵ Kr	4.4(-6)	6.52(-4)	8.63(-4)	8.63(-4)	8.63(-4)	6.52(-4)	6.52(-5)	6.59(-4)
¹³³ Xe	4.0(-4)	0.015	0.017	0.017	0.017	0.015	1.50(-3)	0.013
¹³¹ I	1.86(-4)	1.86(-4)	9.95(-3)	9.95(-3)	9.95(-3)	1.86(-4)	1.86(-5)	7.61(-3)
¹³² I	1.46(-4)	1.46(-4)	3.91(-3)	3.91(-3)	3.91(-3)	1.46(-4)	1.46(-5)	2.98(-3)
Other radionuclides	0.0	0.0	0.0	0.0	0.0	6.3(-4)	0.0	0.031
Whole body submersion doses (rem)	7.4(-4)	0.016	0.032	0.032	0.032	0.017	1.6(-3)	0.055
Whole body inhalation and submersion doses	2.02(-3)	0.017	0.100	0.100	0.100	0.062	1.73(-3)	0.668
Percent of 10 CFR 100 guide- lines (25 rem) for whole body	8.1(-3)	6.8(-2)	0.4	0.4	0.4	0.2	6.9(-3)	2.7

Note: Numbers in parentheses refer to powers of ten, for example, 1.70(-3) = 1.70×10^{-3} or 3.82(4) = 3.82×10^4 .

^aPu dose is 50-year dose.

^bDoses due to release of cell dust containing 0.25 grams of Pu and associated fission products.

^cSharp drop in pressure resulting in 10% of release of cell gases.

^dThe infinite thyroid dose is larger for Cases III, IV, and V than Case VIII because of the larger volume of escaping gas. The larger volume results from heat from lights and equipment on emergency power which is available in Cases III, IV, and V, but not in Case VIII.

TABLE IV.5. Infinite Time^a Doses to Body Organs of Persons at Mud Lake, Idaho
due to Indicated Accidents in HFEF/N

	Type of Accident							
	I	II ^b	III ^c	IV ^c	V ^c	VI ^b	VII ^b	VIII ^d
<u>Inhalation Dose, rem</u>								
<u>Body Organ</u>								
Bone	0.0	0.0	0.0	0.0	0.0	0.200	0.0	1.07
Whole body	1.56(-4)	1.56(-4)	3.59(-3)	3.59(-3)	3.59(-3)	5.37(-3)	1.56(-5)	0.051
Kidney	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.107
Lung (Sol)	0.0	0.0	0.0	0.0	0.0	4.3(-6)	0.0	1.41(-4)
Liver	0.0	0.0	0.0	0.0	0.0	0.027	0.0	0.151
Thyroid	0.088	0.088	2.03	2.03	2.03	0.088	8.8(-3)	1.63
Percent of 10 CFR 100 guide- lines for thyroid	0.029	0.029	0.68	0.68	0.68	0.029	2.9(-3)	0.41
<u>Whole Body Submersion Dose, rem</u>								
<u>Isotope</u>								
⁸⁵ Kr	5.4(-7)	7.95(-5)	4.57(-5)	4.57(-5)	4.57(-5)	7.95(-5)	7.95(-6)	3.65(-5)
¹³³ Xe	4.9(-5)	1.83(-3)	9.15(-4)	9.15(-4)	9.15(-4)	1.83(-3)	1.83(-4)	7.21(-4)
¹³¹ I	2.27(-5)	2.27(-5)	5.27(-4)	5.27(-4)	5.27(-4)	2.27(-5)	2.27(-6)	4.21(-4)
¹³² I	1.78(-5)	1.78(-5)	2.07(-4)	2.07(-4)	2.07(-4)	1.78(-5)	1.78(-6)	1.65(-4)
Other radionuclides	0.0	0.0	0.0	0.0	0.0	7.7(-5)	0.0	2.58(-3)
Whole body sub- mersion dose	9.0(-5)	1.95(-3)	1.69(-3)	1.69(-3)	1.69(-3)	2.03(-3)	1.95(-4)	3.92(-3)
Whole body dose by inhalation and submersion	2.5(-4)	2.1(-3)	5.28(-3)	5.28(-3)	5.28(-3)	7.4(-3)	2.1(-4)	0.055
Percent of 10 CFR 100 guide- lines (25 rem) for whole body	1.0(-3)	8.4(-3)	0.021	0.021	0.021	0.03	8.4(-4)	0.22

Note: Numbers in parentheses refer to powers of ten, for example, 1.70(-3) = 1.70×10^{-3} , or 3.82(4) = 3.82×10^4 .

^aPu doses are 50-year doses.

^bAll material released in two hours. Type F meteorological stability conditions, with a 1-m/sec wind speed, were applied.

^c14.4% of gases were released in first two hours and a total of 25% released in a 30-day period, or a fraction thereof. Of the additional 10% (actually 10.6%) released, one-half was attributed to cell "breathing" caused by atmospheric pressure changes and the other half to expansion resulting from radioactive decay heat. Type F meteorological stability conditions with a 2-m/sec wind speed were applied for 50% of the time and Type B meteorological stability conditions with a 4-m/sec wind speed were used for the other 50% of the time.

^dDuring the first two hours, 5.5% of available fission products and Pu, and 11% of halogen and noble gases were released. In the period of 30 days or less following the incident an additional approximately 10% of the fission products, plutonium, halogens and noble gases escaped. Of this amount, 5% was attributed to cell breathing due to atmospheric pressure changes and the other 5% due to continued expansion of the cell atmosphere from radioactive decay heat. In performing the calculations, it was assumed that a total of 15% (rounded from 15.5%) of the particulates and 20% (rounded from 21%) of the gases escaped to the atmosphere. Type B meteorological stability conditions with a 4-m/sec wind speed were applied for 50% of the time and Type F with a wind speed of 2-m/sec for the remainder. A more refined calculation was possible but was not considered necessary because the dose levels were so low compared to the 10 CFR 100 guidelines.

TABLE IV.6. Infinite Time Dose from Indicated Isotopes to Body Organs of Persons at Site Boundary during First Two Hours after Accident (15-day Cooled Fuel Subassemblies)

Case VIII						
Isotopes	Inhalation Dose, rem					
	Bone	Whole Body	Kidney	Lung (Sol)	Liver	Thyroid
$^{239}\text{Pu}^a$	3.51	0.086	0.368	-	0.478	-
^{90}Sr	5.46	0.316	-	-	-	-
^{144}Ce	2.66	0.118	0.674	-	1.09	-
^{95}Zr	0.98	1.70(-3)	0.204	-	0.160	-
^{140}Ba	0.308	0.025	1.43(-4)	2.48(-4)	4.46(-4)	-
^{141}Ce	0.11	7.79(-3)	0.038	-	0.078	-
^{137}Cs	8.99(-3)	4.94(-3)	4.38(-3)	1.41(-3)	0.012	-
^{134}Cs	3.30(-4)	1.31(-3)	1.14(-4)	3.53(-5)	2.91(-4)	-
^{131}I	-	0.052	-	-	-	29.15
^{132}I	-	2.6(-4)	-	-	-	0.107
Totals	13.04	0.613	1.29	1.69(-3)	1.82	29.26

Whole Body Submersion Dose, rem

^{85}Kr	6.59(-4)
^{133}Xe	0.013
^{131}I	7.61(-3)
^{132}I	2.98(-3)
Particulate fission products	0.031
Total whole body submersion dose	0.055

	Bone	Whole Body	Kidney	Lung (Sol)	Liver	Thyroid
Inhalation and Submersion Dose, rem	13.04	0.668	1.29	1.69(-3)	1.82	29.26
10 CFR 100 Guidelines ⁷	150 ^b	25	-	100 ^b	100 ^b	300
Percent Guidelines	8.7	2.7	-	1.7(-3)	1.8	9.8

Note: Numbers in parentheses refer to powers of ten, for example, 1.70(-3) = 1.70×10^{-3} , or 3.82(4) = 3.82×10^4 .

^aPu doses are 50-year doses.

^bG. L. Voelz, M.D., "Plutonium Dose Criteria for Reactor Safety Analysis," Memorandum, Idaho Operations Office, USAEC (February 14, 1968).

point on its outer boundary who is exposed to the radioactive cloud resulting from the fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure."

The highest dose to any body organ at the site boundary would be 38.2 rem delivered to the thyroid by the iodines. The next largest dose to a body organ would be 13.04 rem to the bone, of which 5.46 rem comes from strontium-90, 3.51 rem from plutonium isotopes and the remainder from various other fission products.

3. Comparison of New and Old Lung Models

The Task Group on Lung Dynamics of the International Commission on Radiation Protection⁸ published a model covering the deposition and retention of materials in the lung for dosimetry of the human respiratory tract. The unit doses resulting from inhalation of various radionuclides, calculated for both the new lung model and the currently-used model, are given in Table IV.7, and are based on a particle size of one micrometer AMAD (Activity Median Aerodynamic Diameter). From this table it is seen that for one-micrometer particles the unit doses determined from the new lung model are appreciably lower than those based on the current lung model. Thus, if the new lung model were used to calculate doses at the site boundary and at the nearest population center (Mud Lake), it is likely that the calculated doses would be lower than, or at least comparable to, those presented in Tables IV.4, IV.5, and IV.6.

4. Summary and Conclusions

The consequences arising from the loss of one or more containment barriers of the HFEF/N facility have been evaluated. Doses incurred by inhalation, by complete submersion within an infinite cloud, and by direct shine with the HFEF/N facility as a point source, were calculated for the site boundary and for Mud Lake, the nearest population center. These calculations show that at the site boundary the two-hour thyroid dose, the largest dose to any critical organ, arising from the postulated accident would be only about 10-13% of the 10 CFR 100 guideline value of 300 rem. At Mud Lake the doses would be substantially smaller.

TABLE IV.7. Comparison of Infinite Time Inhalation Doses Based on Old and New Lung Models for Particle Size 1μ (AMAD)

	$^{239}\text{Pu}^a$	^{90}Sr	^{144}Ce	^{141}Ce	^{137}Cs	^{134}Cs
Dose to Bone, rem/nCi inhaled--Old Lung Model	6.92	0.045	1.21(-3)	1.90(-5)	6.10(-5)	1.46(-5)
Dose to Bone, rem/nCi inhaled--New Lung Model	$\begin{cases} 0.327(\text{PuO}_2) \\ 2.43(\text{Pu}(\text{NO}_3)_4) \end{cases}$	1.25(-3)	7.71(-5)	1.7(-7)	-	-
Whole Body Dose, rem/nCi inhaled--Old Lung Model	0.169	2.66(-3)	5.34(-5)	1.35(-6)	3.37(-5)	5.88(-4)
Whole Body Dose, rem/nCi inhaled--New Lung Model	-	2.5(-4)	4.0(-6)	4.0(-8)	3.7(-5)	6.9(-5)
Liver Dose, rem/nCi inhaled--Old Lung Model	0.939	-	4.94(-4)	1.35(-5)	7.94(-5)	1.29(-5)
Liver Dose, rem/nCi inhaled--New Lung Model	$\begin{cases} 0.204(\text{PuO}_2) \\ 0.377(\text{Pu}(\text{NO}_3)_4) \end{cases}$	-	3.3(-5)	3.5(-7)	-	-
Kidney Dose, rem/nCi inhaled--Old Lung Model	-	-	3.06(-4)	6.56(-6)	-	-
Kidney Dose, rem/nCi inhaled--New Lung Model	-	-	1.9(-5)	1.7(-7)	-	-

Note: Numbers in parentheses refer to powers of ten, for example, $7.2(-3) = 7.2 \times 10^{-3}$, or $8.42(4) = 8.42 \times 10^4$.

^aPu doses are 50-year doses.

Although the above exposures were calculated based on an anticipated typical main cell inventory of 33 subassembly-equivalents, it is possible that the required cell inventory could at times be as much as 4 times larger so that the HFEF/N Facility can meet its operation requirements in support of the LMFBR Program. If the worst conceivable accident were to occur with a cell inventory of 132 subassembly-equivalent, exposures could be increased by a factor of 4 or less, i.e., doses for long-lived isotopes (e.g., ^{239}Pu) could quadruple, but doses from shorter-lived isotopes (e.g., ^{131}I) would not increase significantly. Such exposure would still be well within the 10 CFR 100 guideline values. Accordingly, the main cell inventory which requires cooling will be limited to not more than 132 subassembly-equivalents and a written procedure will be provided to assure that this limit is not exceeded.

Based on the information and analyses presented in this document, it is concluded that there are no credible accidents associated with the operation of HFEF/N Facility that could constitute an undue hazard to the general public at the Site boundary or the nearest community.

SECTION V
ENVIRONMENTAL IMPACT

V. ENVIRONMENTAL IMPACT

A. Character of the Existing Environment

The Hot Fuel Examination Facility is situated at the north end of the ANL-West complex which, in turn, is located in the southeast corner of the Idaho National Engineering Laboratory, approximately 30 miles west of the city of Idaho Falls, Idaho (see Figs. V-1 and V-2). In August 1974, the National Reactor Testing Station was renamed the Idaho National Engineering Laboratory (INEL).

The INEL area is characterized as a cool desert, showing climatological conditions typical of such regions. The climate is dry, with average maximum temperatures ranging from 28°F in mid-January to 89°F in mid-July. Corresponding average minima are 3°F and 51°F. The average annual precipitation is 8.5 inches. The average maximum monthly precipitation occurs in June (1.5 inches) and the minimum in July (0.3 inches). Snowfall averages annually 28.6 inches; two to four 2-week or longer droughts occur during the July-November period. More than 95 percent of the precipitation is evaporated or transpired by plants and less than 5 percent remains in the soil.

The average annual wind speed is 7.5 mph. Calm conditions occur 11 percent of the time ranging from 2 percent of summer afternoons to nearly 25 percent of the time during winter nights. Surface temperature inversions occur nearly every night of the year and occasionally most of the day during December and January. Severe thunderstorms with wind gusts over 50 mph or with hail of 1/2 inch or greater diameter occur with a frequency of less than one per year. Two funnel clouds have been confirmed but no tornados have been reported in 22 years of observations at the INEL.

The topography of the ANL-West site is a shallow, dish-like depression in the low, rolling rises and depressions that characterize this area of the INEL. The ground surface consists generally of composite layers of interbedded volcanic rock and sedimentary material, which includes alluvium, alluvial fan deposits, lakebed and playa deposits, and wind-blown deposits. This material is only a few feet deep covering bedrock. Ground water seeps through the voids and cracks in and between layers of basalt and sedimentary material. The sandy soils are characterized as having high ion-exchange characteristics. The ground water (Snake River Plain aquifer) lies between 600 and 700 feet below the surface in the area. Principal sources of ground water recharge are the Birch Creek Valley and the Big and Little Lost River Valleys to the north, and the Mud Lake area to the northeast.

The Uniform Building Code (UBC), 1970 revision, places the INEL in Seismic Zone 3. Twenty-one earthquakes of sufficient intensity to be classed in Category V of the Modified Mercalli Intensity Scale have been

Fig. V-2. Map of the Argonne-West Site. ANL Neg. No. 103-P5493 Rev. 1.

recorded in Idaho since 1894; two sufficient to be classed in Category VI have been recorded during the past 25 years. The chief epicenters have been more than 100 miles from the INEL.

The most common habitats in the area are desert shrub (dominated by sagebrush, Artemesia tridentata) and mixed grassland. There are large areas of grassland in the ANL-W area, probably due to the slightly increased amounts of moisture received in the form of runoff from the surrounding areas, as well as planted grasses. Invertebrate forms include those common to this type of environment. The compiled catalog of invertebrate species is meager; however, representative species may include (allowing for seasonal variation and effect on life cycles and numbers) locusts, deerflies, houseflies, and an occasional scorpion.

The small mammal population consists primarily of various rodents. Ground squirrels inhabit the sagebrush; mice are found mainly in the grasslands; kangaroo rats are interspersed in the drier, sandier areas. The whitefooted mouse is found in all habitats. Larger mammals include the ever present black-tailed jackrabbit and the cottontail. Coyotes have been observed passing through the middle of the ANL-W facilities and the local area is probably included in the hunting territory of at least a few of these animals. It is logical to assume at least peripheral contact with the ANL-W area of an occasional bobcat or badger. The pronghorn antelope is essentially the only nonpredatory larger mammal.

Wildfowl indigenous to the area include mainly sage grouse, with some raptorial (hawks and eagles) that include the area in their hunting territories. Migratory birds, mourning doves, larks and some hawks are seen. Both the bald and golden eagle have been observed in the area. Both are protected by state and federal regulations and the bald eagle is listed as an endangered species. Waterfowl have been observed on the industrial waste pond in spring and fall. The industrial waste pond has, in the past, served as a focal point of utilization and connection between ANL-W and the surrounding environment; for example, as mentioned, ducks and geese have been observed utilizing the industrial waste pond for resting and ostensibly feeding. Coyotes have been observed utilizing the pond as a watering area. It can be assumed that other organisms similarly utilize the pond. The reptile population of the area is small and consists mainly of lizards, horned toads, and desert rattlesnakes. All components of utilization of ANL-W by different species are not known. The preceding information is based upon visual observation, previously collected data from other sources, and logical assumptions based on apparent ecological constants. In all, however, there exists a high degree of compatibility between the area and organisms found within it. The ANL-W area is within federal control. Access is limited and hunting is not permitted. There is no farming or agriculture in the area, although sheep are allowed to graze a large part of the fringe area of the INEL in spring and fall.

An occasional artifact of earlier history has been found by workmen in the area; however, the ANL-W area has, to date, been of no significant importance to archeologists or anthropologists. The settlements nearest to the site, outside of other INEL installations, are Mud Lake (~7 miles), Atomic City (~25 miles), Howe and Idaho Falls (~30 miles), and Butte City and Arco (~35 miles).

Monitoring of the INEL environment is done by the ERDA's Health Services Laboratory (HSL) primarily for isotopic activity. Their environmental monitoring reports are issued biannually. Ground water is sampled weekly by HSL at 23 production wells at the station and tested for radioactivity. Twelve wells outside the INEL boundaries are sampled semiannually and analyzed for radioactivity. A continuous, weekly air sampling program for analyzing radioactivity is maintained at eight on-site and ten off-site locations. The concentrations of suspended particulate material and natural dustfall rates are measured as well. Samples of INEL soil have been analyzed for radioactivity. Direct radiation is measured at locations on and near the station, including all nearby population centers. Samples of foodstuffs are analyzed for specific radionuclides (^{131}I , ^{137}Cs , ^{90}Sr). Grade A and B milk samples are obtained weekly and monthly respectively.

B. Impact of Normal Operations

1. Gaseous Radioactive Effluents

Gaseous radioactive effluents from HFEF/N may be present in suspect air from work areas, including cells, glove boxes, hoods, etc. The radioactive component of the effluent is projected to have a representative composition of ^{133}Xe (68%, 5.3 day half-life) and ^{85}Kr (32%, 10.7 year half-life). All suspect air is sent through a series of HEPA filters before release to the stack. The postulated level of release when the HFEF/N facility is in full steady-state operation, including destructive examinations in the Main Cell, is 3 pCi/cc from the building stack. This is well below the release limit of 10 pCi/cc set in ERDAM Appendix 0524 for ^{85}Kr and is smaller by a factor of 10 than the release limit (30 pCi/cc) set by ERDA-ID Appendix 0510.

Further, the rare gases krypton and xenon are biologically inactive. They are not involved in metabolism nor incorporated into biological molecules. These facts, coupled with the low level of release projected lead to the conclusion that there will be no adverse environmental effects resulting from release of radioactive gases under normal operating conditions even when the facility is in full operation.

2. Liquid Suspect Wastes

It is estimated that under full operating conditions there will be a flow of approximately 6500 gallons per month of liquid wastes that may be

considered suspect. Sources of this potentially contaminated water include laboratories, decontamination areas, and hot change rooms, as well as suspect and hot repair rooms. This suspect liquid is routed ultimately to the evaporator retention tanks in the basement of the Laboratory and Office Building. The retention tanks form a part of the ANL-West liquid suspect waste system. This system handles, treats, and packages liquid suspect wastes from the entire ANL-West area. The liquid wastes are evaporated and exposed to ion-exchange resin to reduce activity in the effluent stream, which is then released to the liquid industrial waste pond.

At present all suspect liquid effluents to the industrial waste lagoon do not exceed AEC-10CFR 50 guidelines for yearly release. Average activity in releases from suspect liquids is less than three curies per year, two curies per year below the proposed 10CFR 50 guidelines for yearly isotopic release. The improvements resulting from planned modifications to the suspect liquid waste system will, after treatment, reduce the activity in the effluent stream by a factor of 2×10^3 below current releases, or to an estimated 0.001 Ci/yr. It has been concluded in the Environmental Analysis of Modifications to the Radioactively Suspect Liquid Waste System (document #W7500-0901-SA-00) that there will be negligible adverse ecological effects resulting from the processed effluent stream; therefore, the fractional contribution of suspect liquid effluent from HFEF/N is not expected to cause any significant deleterious environmental effect after release to the environment by way of the suspect liquid waste system.

3. Solid Wastes

Although there is no available catalog of the specific isotopes anticipated as solid waste from HFEF/N, it is estimated that there will be 2500 cubic feet of low-level wastes generated each year under full operating conditions. The total activity of these wastes will be about 2.5 Ci. It is further projected that there will be 48 containers (6 x 1 ft) of solid radioactive wastes of high activity level generated each year. Each container will have about 1×10^4 Ci activity. It is planned that both the low-level wastes and the high-level wastes in the 6-ft containers will be put in interim storage at the EBR-II high-level waste storage facility.

The construction of the containers (generally concrete or reinforced concrete) handling and packaging procedure, and storage selection, utilization, and reinforcement will follow ERDAM-0529 regulations and guidelines with regard to packaging, containment, temporary storage and recovery of high-activity-level solid wastes. In addition, adherence to ERDAM-0511 and -0510 guidelines for environmental monitoring and air and water pollution standards will help insure containment of solid radioactive wastes from HFEF/N, and ensure that there will be no unplanned or uncontrolled exposure of radioactive solid wastes to the surrounding environment.

4. Industrial Effluents

No projected figures are available for the amounts of nonradioactive solid wastes resulting from HFEF/N activities; however, nearly all (approximately 2.5 tons per week) industrial solid waste from ANL-West is removed to the Central Facilities landfill operated by Aerojet Nuclear Corporation. Since no disposal is done at the ANL-W site, solid nonradioactive wastes from HFEF/N operations will be transported to the Central Facilities landfill and should not create any adverse environmental problems.

Liquid industrial waste water from HFEF/N is estimated to be 40,000 gallons per week during peak operational periods. This waste water will be run through a separate line from those used for suspect liquid wastes. Included as sources of liquid industrial waste are cooling water from the evaporatively cooled air supply and air conditioners, as well as any industrial waste water not sent through the suspect waste lines. As the amount of industrial waste water from all site activities is approximately 700,000 gallons weekly, the fractional increment (about 6%) of nonradioactive suspect liquid industrial waste water from HFEF/N operations is not expected to be a consequential environmental consideration.

Since HFEF/N receives steam energy during normal operations from the boilers in the EBR-II power plant, gaseous industrial effluents resulting from the existence of HFEF/N must also be considered as incremental contributors to the main stack. There are no data available for release rates and amounts of carbon monoxide, nitrogen oxides, hydrocarbons and photochemical oxidants. Levels of sulfur dioxide, hydrogen, carbon dioxide, chromate and particulates from the main stacks have, to date, not been shown to be environmentally deleterious. It is logical to assume, then, that additional stack contributions of industrial gases caused by the presence of HFEF/N will not be a significant source of environmental impact.

5. Sewage Effluents

Sewage effluent from HFEF/N runs into the EBR-II sewage lagoon. Biological degradation (aerobic and anaerobic) proceeds continuously in the lagoon and water is dissipated by solar evaporation. Total site release is approximately 250,000 gallons per month, a fraction of which will come from HFEF/N operations. Only organic matter is pumped to the sewage lagoon. The lagoon is a controlled aquifer used for this purpose only; therefore, pollution as a result of eutrophication and/or the potential for contamination is reduced and contained and no deleterious environmental effects are expected.

C. Impact of Accident Conditions

A strict assessment of the effect on the environment of an accidental release of radioactivity from HFEF/N involves a determination of the impact

of such activity releases on man, on the movement of radionuclides through the food chain, and the effects of radiation on other biota. Various potential accident situations are analyzed in Section IV.C of this report. There it is shown that even under the incredible circumstances where all containment barriers are violated, the dose rates to man resulting from the levels of radioactive materials at the site boundary and beyond are below the 10CFR 100 guideline limits. However, there are no comparable guidelines that apply to food chains in the environment or to the effects on plants and animals.

It is recognized that some small rodents and jackrabbits in close proximity to the facility may be exposed to a relatively intense direct radiation field. The integrated doses might be sufficiently high to cause the death of some individual rodents, either directly or as the result of an induced cancer; however, the impact on the rodent population in the area will not be significant.

Similarly, large mammals, such as antelope, could be near the facility fence during the release and thus be exposed to higher concentrations of contaminated air than the hypothetical individual located at the site boundary. In addition, some of the released isotopes, notably radioiodine, will be deposited on forage at downwind locations and foraging species could ingest quantities of radioactivity which would result in significant thyroid doses. The probability of death from thyroid cancer would be increased for the exposed animals, but the effect, if any, on these individuals would not alter the species balance in the area.

More than half the land area of the INEL is opened for grazing through a cooperative agreement between the ERDA and the Bureau of Land Management. The grazing area nearest the HFEF/N is approximately $2\frac{1}{2}$ miles to the northeast. The ERDA requires notification by the grazer when his flocks enter INEL land as well as information on their expected route and the duration of their stay. The herders and flocks are under ERDA control during their stay onsite; in the event of an accidental release they would be directed away from the path of the plume and the potentially contaminated forage.

It would appear to be a reasonable conclusion that if at the site boundary the levels of radioactive debris from the maximum catastrophe are well below those which result in an acceptable once-in-a-lifetime accidental dose to man, then the effects on other components of the environment must be at least as small. On this basis it is concluded that the impact of HFEF/N on the environment even under accident conditions up to and including the maximum catastrophe, is acceptably low.

SECTION VI
CONCLUSIONS

VI. CONCLUSIONS

Safety in design, operation and procedures of HFEF/N has been of paramount concern since the inception of the project. The facility has been designed to codes and standards applicable at the time of design. The design itself is such as to minimize the possibilities for accidents. Some eight years' experience with HFEF/S (first as the Fuel Cycle Facility, then the Fuel Examination Facility), following a decade of experience with other hot cells designed and operated by Argonne, has provided the basis for many improvements incorporated in the design of HFEF/N.

Operations will be in accordance with the HFEF/N Operation and Maintenance Manual and other applicable requirements, and will be performed by personnel who have completed a formal training program. Operating personnel will be supervised by trained and experienced supervisors. Formal emergency procedures have been developed and all personnel have received instruction in these procedures.

Evaluations have been made of the safety aspects of the design and the proposed operations. It has been shown that safety features adequate to protect against the occurrence of a serious accidental release of radioactivity have been designed into the facility. However, even in the case of the maximum catastrophe, it has been shown that resulting off-site releases of radioactive materials result in doses at the site boundary and beyond which are far below the 10 CFR 100 guidelines.

On the basis of the design, the operations to be performed and procedures to be followed, and evaluations of the safety precautions taken, it is concluded that HFEF/N can be operated without undue hazard to the public or to the environment.

APPENDIX A
CONTROL PANEL PARAMETERS AND
ANTICIPATED SET POINTS

APPENDIX A

Control Panel Parameters and Anticipated Set Points

The parameters and set points that are annunciated on the control panel in the operations office are listed below. These are signals related to the facility operational systems and are in addition to the radiological monitoring signals.

Number	Nameplate	Alarm Set Point	Normal Oper. Range	Parameter
1	Main Argon Supply Low Pressure	50 psi	60-70	Pressure
2	Main Argon Supply Low Temp	-40°F	AMB temp	Temperature
3	Emergency Argon Supply Low Pressure	1200 psi	2000 psi	Pressure
4	Main Cell Atmosphere High Pressure	-0.75 in. H ₂ O	-2.5 in. H ₂ O	Pressure
5	Main Cell Atmosphere Low Pressure	-6 in. H ₂ O	-2.5 in. H ₂ O	Pressure
6	Main Cell Atmosphere High Temp	105°F	75 to 95°F	Temperature
7	Main Cell Atmosphere Low Temp	65°F	75 to 95°F	Temperature
8	Emergency Argon Supply On	-8 in. H ₂ O or manual	-2.5 in. H ₂ O	Pressure
9	Main Cell Atmosphere High Oxygen	Not operational	25 to 50 ppm	Current of O ₂ cell
10	Main Cell Atmosphere Low Oxygen	Not operational	25 to 50 ppm	Current of O ₂ cell
11	Main Cell Atmos. Filters High Diff. Pressure	-3 in. H ₂ O	-1 in. H ₂ O	Change in pressure
12	Main Cell Exhaust Filters High Diff. Pressure	-3 in. H ₂ O	-1 in. H ₂ O	Change in pressure
13	Met Box Off Normal	As required	As required	Pressure and as required
14	Main Cell Atmosphere High Moisture	Not operational	40 to 50 ppm	Current of O ₂ cell produced by electro-decomposition of H ₂ O
15	Main Cell Atmosphere Low Moisture	Not operational	40 to 50 ppm	Current of O ₂ cell produced by electro-decomposition of H ₂ O
16	Main Cell Refrigeration unit "A" malfunction CH101A	OFF	ON or standby	Voltage to R3 and R4
17	Main Cell Refrigeration unit "B" malfunction CH101B	OFF	ON or standby	Voltage to R3 and R4
18	Coolant Expansion Tank Low Level	12 gal	20 gal	Level proper capacitance
19	Coolant Expansion Tank Low-Low Level	2 gal	20 gal	Level proper capacitance
20	Coolant Expansion Tank High Pressure	25 psi	15 psi	Pressure
21	Purif. Loop Cooler "A" Leak HX-1A	Leak	No leak	Change in capacitance
22	Main Cell Cooling Coil "A" Leak CC-1A	Leak	No leak	Change in capacitance
23	Main Cell Cooling Coil "B" Leak CC-1B	Leak	No leak	Change in capacitance
24	Main Cell Purif. Loop Regen. HTR - High Temp H-1	1400°F	1250°F OFF - ON control	Temperature (EMF)
25	Coolant Expansion Tank Low Pressure	10 psi	15 psi	Pressure

Number	Nameplate	Alarm Set Point	Normal Oper. Range	Parameter
26	Main Cell Cooling Blower "A" Failure B-1A	Malfunction	ON or standby	Voltage to motor
27	Main Cell Cooling Blower "B" Failure B-1B	Malfunction	ON or standby	Voltage to motor
28	Main Cell Cooling Blowers Failure B-1A & B-1B	Malfunction of both	One or both operating	Change in pressure to 2 in. H ₂ O
29	Rabbit Transfer	As required	As required	As required
30	Bearing Temperature Annunciator AN-6	Any "AN-6" malfunction	All temp below set points	Temperature (EMF)
31	S/A Pit Cooling Blower "A" Failure B-2A	Malfunction	Operating or standby	Voltage on motor
32	S/A Pit Cooling Blower "B" Failure B-2B	Malfunction	Operating or standby	Voltage on motor
33	S/A Pit Cooling Circuit A Abnormal Flow	Hi/Lo Flow	20 scfm to each S/A (minimum)	Pressure drop across FE in supply to circuit
34	Cell Exhaust System High Plenum Pressure	-4 in. H ₂ O	5.5 in. H ₂ O	Pressure
35	Building-Lab Exhaust System High Plenum Pressure	0.875 in. H ₂ O	1.25 in. H ₂ O	Pressure
36	Refrig. Air Supply System Low Preheat Temp	35° to 37°F	58°F	Temperature
37	Evap. Cooled Supply System Low Preheat Temp	35° to 37°F	60° to 70°F	Temperature
38	Refrig. Air Supply System Low Flow	<0.5 in. H ₂ O		Pressure
39	Evap. Cooled Supply System Low Flow	<0.5 in. H ₂ O		Pressure
40	Cell Exhaust Fan "A" Fan Failure 4-A	Failure	Operating or standby	Voltage to motor
41	Cell Exhaust Fan "B" Fan Failure 4-B	Failure	Operating or standby	Voltage to motor
42	Building-Lab Exhaust Fan "A" Fan Failure 5-A	Failure	Operating	Voltage to motor
43	Building-Lab Exhaust Fan "B" Fan Failure 5-B	Failure	Operating	Voltage to motor
44	Decon Cell High Pressure	>-0.35 in. H ₂ O	-0.50 in. H ₂ O	Pressure
45	Hot Repair Area High Pressure	>-0.12 in. H ₂ O	-0.25 in. H ₂ O	Pressure
46	Plant Air Comp. Low Pressure	<85 psi	92 psi	Pressure
47	Instrument Air Comp. Low Pressure	<80 psi	92 psi	Pressure
48	Tower Cooling Water Low Temp	<40°F	60°F	Temperature
49	Tower Cooling Water High Temp	>72°F	60°F	Temperature
50	Tower Cooling Water Pump Failure	Malfunction	Operating	Change in pressure
51	Laboratory Water System Low Pressure	45 psi	>45	Pressure
52	Lab Drain Retention Tank Hi-Level	19 in.	<19 in.	Conductance at 17-in. level
53	Decon Drain Holdup Tank Hi-Level	17 in.	<17 in.	
54	Tank Room Suspect Waste Sump Hi-Level	<Overflow automatic pump out	Below alarm point	High float level
55	Decon Suspect Waste Sump Hi-Level	~3 ft from overflow automatic pump out below 3 ft from top	<3 ft from overflow	High float level
56	Transfer Hydraulic System Low Pressure	225 psi	280 psi	Pressure
57	Leak Monitoring System Off Normal	Loss of flow	0.5 to 4.5 psi	Pressure

One of the above signals will show trouble with the temperature of any of the bearings monitored on annunciator panel No. 6. The bearings so monitored are listed below. The operational temperatures and the alarm set points given in the table are those for air and may be modified somewhat when the bearings are used in an argon atmosphere, if experience shows this to be necessary.

Number	Nameplate	Alarm Set Point (°F)	Normal Oper. Range (°F)	Parameter
1	Main Cell Cooling Blower "A" Opp. End Bearing High Temp	150	100	Temperature
2	Main Cell Cooling Blower "A" Shaft End Bearing High Temp	150	100	Temperature
3	Main Cell Cooling Blower "B" Shaft End Bearing High Temp	150	100	Temperature
4	Main Cell Cooling Blower "B" Opp. End Bearing High Temp	150	100	Temperature
5	Spare			
6	S/A Pit Cooling Blower "A" Shaft End Bearing High Temp	230	200	Temperature
7	S/A Pit Cooling Blower "A" Opp. End Bearing	240	200	Temperature
8	S/A Pit Cooling Blower "B" Shaft End Bearing High Temp	230	200	Temperature
9	S/A Pit Cooling Blower "B" Opp. End Bearing High Temp	235	200	Temperature
10	Spare			
11	Main Cell Purif. Loop Comp. "A" Shaft End Bearing High Temp	225	200	Temperature
12	Main Cell Purif. Loop Comp. "A" Opp. End Bearing High Temp	225	200	Temperature
13	Main Cell Purif. Loop Cooler "A" High Temp	150	100	Temperature
14	S/A Storage Pit Cooling High Temp	175	100	Temperature
15	Alarm Resets & Set Points			
16-17	Spare			
18	Main Cell Purif. Loop Comp. "B" Shaft End Bearing High Temp.	225	200	Temperature
19	Main Cell Purif. Loop Comp. "B" Opp. End Bearing High Temp.	225	200	Temperature
58	S/A Pit Cooling Circuit B Abnormal Flow	Hi/Lo Flow	20 scfm to each S/A (minimum)	Pressure drop across FE in supply to circuit
59	Argon Cooler HX-1B Leak	Leak	No leak	Change in capacitance
60	Spare			

APPENDIX B
TECHNIQUE FOR
CALCULATING RADIATION DOSES

APPENDIX B

Technique for Calculating Radiation Doses

This appendix describes the assumptions made and the equations used for calculating the radiation doses at the site boundary and at Mud Lake.

1. Inhalation Doses

The infinite time dose, D_{∞} , by inhalation of radioactive material to a critical organ¹⁰ is given by

$$D_{\infty}(\text{rem}) = \frac{854 A_{\tau} f_a T_e \sum E_i (\text{RBE}) F_i n}{m} \left[1 - \exp\left(\frac{-0.693}{T_e} t\right) \right] \quad (1)$$

If the effective half-life is short compared to the time during which the organ dose is received, the term $1 - \exp[(-0.693/T_e)t]$ approaches 1 and may therefore be omitted. In Eq. 1,

A_{τ} = curies inhaled;

f_a = fraction of a radionuclide inhaled that is translocated to a critical organ;

T_e = effective half-life in the body in seconds; $1/T_e = 1/T_r + 1/T_b$, where T_r is the physical half-life and T_b is the biological half-life;

t = time in seconds during which the organ dose is received;

m = mass of the critical organ in grams;

and

$\sum E_i (\text{RBE}) F_i n$ = effective energy absorbed per disintegration in MeV;
 E_i is the energy of the isotope per disintegration,
 RBE is the relative biological effectiveness, n is the "damaging factor," and F_i is the ratio of daughter disintegration to that of the parent.

Values for f_a , T_e , m , and $\sum E_i (\text{RBE}) F_i n$ were taken from Ref. 11.

Values for m for the standard man are as follows:

<u>Organ</u>	<u>Mass, g</u>	<u>Organ</u>	<u>Mass, g</u>
Total body	7×10^4	Liver	1700
Bone	7×10^3	Lung	1000
Kidney	300	Thyroid	20

The number of curies inhaled, A_τ , is given by

$$A_\tau = RQ_t \frac{\chi}{Q}, \quad (2)$$

where

R is the breathing rate taken as 10 m^3 in 8 hr or $3.5 \times 10^{-4} \text{ m}^3/\text{sec}$ (from Ref. 5),

Q_t is the total number of curies of the particular isotope passing over the observer in time t ,

and

$$\frac{\chi}{Q} = \frac{1}{\pi \bar{\mu} \sigma_y \sigma_z} \exp\left(-\frac{h^2}{2\sigma_z^2}\right). \quad (3)$$

Here

$\bar{\mu}$ = the windspeed in meters per second,

σ_y = the horizontal distance (in meters) perpendicular to the centerline where the concentration falls to a value of 0.61 times the centerline concentration (values of σ_y were determined from Ref. 12),

h = height of the release point (meters) = 29.3 meters for HFEF/N,

χ = concentration in curies per cubic meter,

and

Q = emission rate in curies per second.

For Type F meteorological stability conditions with a windspeed of 1 m/sec at the site boundary, $\chi/Q = 3.97 \times 10^{-5} \text{ sec/m}^3$. At Mud Lake, $\chi/Q = 0.51 \times 10^{-5} \text{ sec/m}^3$ (from Ref. 12).

Through the use of Eqs. 1-3, one is able to calculate the infinite dose to an organ from inhaling a given number of curies of a radionuclide. The entries of Tables IV.4 through IV.6 have been obtained from the application of these equations. Table IV.6 is based on a selected number of radionuclides. The dose values obtained from using the isotopes represent over 90% of those obtained from using the expanded list shown in Table IV.3.

In Eq. 3, the term $\exp(-h^2/2\sigma_z^2)$ represents the reduction in ground concentration because the effluent was released at a height h instead of at ground level. At the site boundary for Type F meteorological stability conditions, $\sigma_z = 36 \text{ m}$; at Mud Lake, $\sigma_z = 71 \text{ m}$; the reduction factors are 0.72 and 0.92, respectively. This shows that at the site boundary, the doses are

about two-thirds as great as those from a ground source, but at the greater distance, the stack loses its effectiveness; i.e., the doses with the stack are over 90% as great as those obtained from a ground source. The stack is much less effective under unstable conditions.

In calculating the 30-day dose received by persons at Mud Lake, Type B meteorological stability conditions based on the Pasquill-Gifford curves with a windspeed of 4 m/sec were applied 50% of the time, and Type F meteorological stability conditions with a windspeed of 2 m/sec were applied the rest of the time. This is a crude way to approximate the meteorological conditions over a 30-day period and provides doses five to ten times higher than really would occur. For example, to assume that the wind is unchanging and blows only from HFEF/N to Mud Lake for 30 days is unrealistic. To assume a windspeed of 2 m/sec or less for 50% of the time is also unduly severe. However, the dose levels, even under unrealistically severe conditions, were sufficiently low that calculation based on more refined techniques appeared unwarranted. The data shown in Table IV.5 may be considered an extreme upper bound.

2. Submersion Doses

The beta or gamma dose¹⁰ to a person standing on the ground, from an effectively semi-infinite cloud of radionuclides surrounding him, may be obtained from

$$D_{\infty}(x,y,0) = C_1 \bar{E} \Psi(x,y,0) \frac{\rho_0}{\rho}, \quad (4)$$

where

$D_{\infty}(x,y,0)$ = the dose (either beta or gamma) in rem to a person standing on the ground at a point (x,y), where the origin is at the source point, x is the distance downwind, and y is the distance in the transverse direction, i.e., perpendicular to the downwind direction;

C_1 = a constant; $C_1 = 0.23$ for beta radiation, and 0.25 for gamma radiation;⁶

$\bar{E}$ = the mean effective energy per disintegration in MeV;

$\Psi(x,y,0)$ = the time-integrated concentration in Ci-sec/m³;

ρ_0 = the air density under standard conditions = 1293 g/m³;

and

ρ = the actual air density in g/m³.

For beta emitters, the dose is generally a surface body dose.

The external dose from a cloud passing over the observer from the maximum catastrophe (type VIII) is substantially lower than the 10CFR 100 guideline as indicated in Tables IV.4, IV.5, and IV.6.

The gamma doses from the radionuclides in the HFEF/N facility following a Type VIII accident is infinitesimal at the site boundary, even though the attenuation due to the building or the cell walls is neglected. These doses may be calculated from¹⁰

$$D_r = 0.0404 \frac{\mu_a Q \bar{E}_\gamma (1 + \mu k r) \exp(-\mu r)}{r^2}, \quad (5)$$

where

D_r = gamma dose in rem to a person at a distance r in meters,

μ_a = energy-absorption coefficient for air in meters⁻¹ due to energy absorption due to electron recoil,

μ = total energy absorption in air in meters⁻¹,

$k = (\mu - \mu_a)/\mu_a$,

$\bar{E}_\gamma$ = average gamma energy emitted per disintegration in MeV/disintegration,

and

Q = number of curies of gamma emitters.

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REFERENCES

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