C.6.0 VITRIFICATION FACILITY PROCESS SYSTEMS

The process mission of the Vitrification Facility (VF) is to convert the high-level radioactive waste from its initial sludge/liquid form into borosilicate glass in stainless steel canisters. The filled canisters are stored temporarily in the High-Level Waste Interim Storage (HLWIS).

The VF operates on a continuous basis (24 hours per day, 7 days per week). Feed preparation for the vitrification operation is done on a batch basis. The total vitrification campaign, producing glass at a nominal rate of 30 kg/hr (66 lb/hr), is expected to produce approximately 500,000 kg (1.1E+06 lb) of glass (about 300 canisters).

The VF consists of several associated structures, including the Transfer Trench, the Vitrification Building (which includes the Vitrification Cell, operating aisles, and Control Room), the Cold Chemical Building, the 01-14 Building, the Transfer Tunnel, the Load-In Building, the Equipment Decontamination Room (EDR), the HLWIS, the Off-Gas Trench, and the Diesel Fuel Oil Storage Tank Building. The relative locations of these structures are shown in Figure C.1.2-1. Figure C.6-1 is a flow diagram that includes the Tank Farm (covered in other DOE-approved West Valley Demonstration Project (WVDP) safety documentation) and VF process operations. The VF process operations begin with the slurry transfer pump located in Pit 8Q-2 (pump pit for Tank 8D-2), which discharges to the double-walled transfer piping located in the Transfer Trench. VF process operations include the following functions:

- High-Level Waste (HLW) transfer from the Waste Tank Farm to the Vitrification Building.
- Preparation of cold (i.e., nonradioactive) chemicals in the Cold Chemical Building.
- Melter feed preparation in the Concentrator Feed Make-up Tank (CFMT).
- Feed transfer from the CFMT to the Melter Feed Hold Tank (MFHT).
- Transfer from the MFHT to the Slurry-Fed Ceramic Melter (SFCM).
- SFCM operation and transfer of molten HLW glass to canisters.
- Filled canister in-cell storage, welding, decontamination, and transfer to and storage in the HLWIS until the geologic repository is available for permanent disposal.

- Process equipment for off-gas collection, quenching/scrubbing, treatment, filtering, and monitoring before Main Plant stack release.
- Vitrification Cell ventilation exhaust air filtering and monitoring before stack release.
- Load-In Building (for introduction of empty canisters and interim storage racks into the EDR).

Table C.6-1 describes the primary steps in the process to accomplish vitrification and canister filling of the high-level Tank Farm waste. Detailed mass balance and radioactivity balance information is found in Nixon (May 1, 1995).

After cooling, the lid to the filled waste canister is remotely seal-welded in place. The canister is then processed through a remotely operated decontamination station. After decontamination, the canister is loaded onto a remotely operated rail cart by the in-cell crane. The cart transfers the filled waste canisters into the HLWIS where they are remotely off-loaded by an in-cell crane for interim storage.

The remainder of this chapter presents detailed discussions of the VF systems and processes under the subsections: C.6.1 Vitrification Process Systems; C.6.2 Process Chemistry; C.6.3 Off-Gas Treatment, Facility Vent, and Liquid Waste Systems; C.6.4 Mechanical Systems; C.6.5 Process Support Systems; C.6.6 Control Systems; and C.6.7 Sampling and Monitoring Systems.

The discussion which follows is intended as an overview to show the inter-relationship between major portions of the WVDP HLW complex, some of which is described in other DOE-approved WVDP safety documentation. The Vitrification Cell is the "heart" of the HLW processing operations covered by this Final Safety Analysis Report (FSAR). Thus, the discussion of system interfaces is introduced with the cell and expanded to the interfacing buildings and systems.

The Vitrification Cell interfaces with the Sludge Mobilization System (SMS), Cold Chemical Building, ex-cell Off-Gas system, HLWIS, Main Plant Analytical Laboratory, and the supporting utilities.

The Vitrification Cell interfaces to and from the SMS are as follows:

- HLW Tank 8D-2 to CFMT
- CFMT to HLW Tank 8D-2
- Condenser to HLW Tank 8D-3

- Waste Header to HLW Tank 8D-4

The Vitrification Cell process interfaces from the Cold Chemical Building are as follows:

- Holding Tank (65-D-02) to CFMT
- Holding Tank (65-D-02) to MFHT
- Main Mix Tank (65-D-03) to CFMT
- Main Mix Tank (65-D-03) to MFHT
- Shim Tank (65-D-04) to CFMT
- Shim Tank (65-D-04) to MFHT
- Cold Chemical decontamination solution make-up tanks to various in-cell vessels. (See Section C.6.5.1.3.)

The Vitrification Cell interfaces to the Off-Gas system are:

- In-cell preheaters to 01-14 Building moisture entrainment separator

The Vitrification Cell interfaces to and from the HLWIS and Load-In Building:

- Transfer Cart to storage racks in the HLWIS
- Canister port, mandoor, and shield doors at the Load-In Building/EDR interface to transfer mechanisms (e.g., the Transfer Cart and EDR bridge crane)

The Vitrification Cell interfaces with the Analytical Laboratory located in the Main Plant:

- Pneumatic transfer of slurry and glass shard samples from the Vitrification Cell

The utilities provided to the VF by the Plant systems and internal supply functions can be summarized as:

Plant systems:

- Cooling Tower Water

- Chilled Water
- Demineralized Water
- Electrical Distribution
- Instrument Air
- Potable Water
- Steam and Condensate
- Utility Air
- Utility Water
- Drains

Internal systems:

- Refrigerant for Heating, Ventilation, and Air Conditioning (HVAC)
- Cover Gas for Welding
- Chilled Water for HVAC
- Dry Air part of the Utility Air system
- High Pressure Air for Instrument Air

The VF also has internal systems and interfaces with the WVDP site systems or functions. The interfaces are as follows:

- Fire Detection and Protection system
- Radiation Monitoring system
- External and Internal Communication systems (radios, telephones and intercom)
- Personnel Protection Equipment such as showers and eye washes and emergency medical equipment and supplies

The following utilities are supplied to the Cold Chemical Building from the Vitrification Building utilities:

- Demineralized Water
- Electrical Distribution
- Potable Water
- Instrument Air
- Utility Air
- Utility Water
- Steam and Condensate
- Cooling Tower Water

The following utilities are supplied to or support the Ex-Cell Off-Gas system:

- Demineralized Water
- Cooling Water
- Electrical Distribution
- Instrument Air
- Utility Air
- Drains
- HVAC

The HLWIS major process systems interface with the in-cell remote handling and viewing equipment used to remove the canister from the cart and place it in the storage rack.

The following utilities are supplied to the HLWIS:

- Electrical Distribution
- HVAC from the Main Plant system

C.6.1 Vitrification Process Systems

C.6.1.1 HLW Tank Farm Feed Preparation and Transfer

The HLW to be vitrified is located in Tank 8D-2 in the underground Tank Farm adjacent to the Vitrification Building. The HLW originally consisted of sludge and an overlying liquid supernatant, known as PUREX. Before transfer of the HLW to the Vitrification Building, the supernatant as well as sludge wash pretreatment liquid was processed through the Integrated Radwaste Treatment System (IRTS), consisting of an ion exchange process in Tank 8D-1 to remove cesium, concentration by evaporation, and solidification in a cement matrix. The ion exchange medium (zeolite), with its adsorbed cesium (along with lesser amounts of plutonium and strontium from use of titanium-treated zeolite), has been transferred to Tank 8D-2 to be mixed with the HLW for vitrification. In addition, the neutralized THOREX waste from Tank 8D-4 has been well mixed in Tank 8D-2.

The Tank 8D-2 sludge is well mixed into a slurry and transferred to the CFMT via 304L stainless steel double-walled containment pipe within the Transfer Trench.

C.6.1.2 Vitrification Cell

The "heart" of the vitrification process is located in the Vitrification Cell. A cut-away view of this cell is shown in Figure C.6.1.2-1. The locations of Vitrification Cell process vessels and equipment, including the CFMT, MFHT, SFCM, turntable, off-gas treatment equipment, canister welding station and the canister decontamination station are shown in Figure C.6.1.2-1. Vitrification Cell operations are performed remotely by operators situated at control consoles in the VF Control Room and/or the Operating Corridor. Remotely operated equipment includes, but is not limited to, in-cell system valves, pumps, jets, cranes, electro-mechanical manipulators, remote manipulators, and remotely controlled closed-circuit television (CCTV). Operations are also observed through shield windows from the Operating Corridor.

Filled canisters are transferred from the Vitrification Cell to the HLWIS, through the Transfer Tunnel using a remotely operated rail transfer cart as shown in Figure C.6.1.2-2. Loading and unloading operations are performed remotely by operators in the VF Control Room and/or Operating Corridor.

The Operating Corridor is located around the Vitrification Cell and allows viewing of Vitrification Cell operations through shielded windows and in-cell CCTV with pan-and-tilt capabilities, and control of operations through control consoles and related remote manipulators, electro-mechanical manipulators, and in-cell cranes with specially designed remote handling fixtures and grapples. The VF Control Room, located off the Operating Corridor, provides a central area where operating documents, drawings, and overall process monitoring equipment is located.

C.6.1.3 Vitrification Facility Slurry Receipt and Preparation

C.6.1.3.1 Concentrator Feed Makeup Tank

The CFMT is used for HLW feed preparation. Figure C.6.1.3-1 is an engineering drawing of the CFMT, which has a maximum volume of approximately 23 m^3 (6,076 gal). It receives all process constituents, including well mixed HLW from Tank 8D-2, glass formers and other chemicals and liquid recycle streams from the Submerged Bed Scrubber (SBS). Chemicals required for feed preparation (e.g., nitric acid, sucrose, glass formers, and demineralized water) are provided from the Cold Chemical Preparation and Feed system.

All CFMT vessel components (but not all replaceable components) wetted by the waste slurry are made of Hastelloy C-22. The C-22 alloy was chosen based on corrosion tests using boiling waste slurry. Pitting or crevice corrosion are not expected in the vessel and general corrosion is anticipated to be less than 2.5E-04 mm (1.0E-05 in) per year, which is below the corrosion allowance of 1.6 mm (0.063 in). Components which do not see boiling process fluids are fabricated from 304L stainless steel. The vessel flanges are fabricated of Hastelloy C-22 for all connections greater than 76 mm (3 in). The largest diameter flange is for the agitator, at 1,168 mm (46 in). Flange gaskets are Viton attached to a 304L stainless steel carrier. Replaceable components, such as jumpers, are also fabricated from 304L stainless steel.

The CFMT exterior is partially covered by two half-pipe coil heating/cooling jackets: one on the wall and one on the bottom head. The coils are made from nominal size 89-mm (3.5-in) schedule 10 pipe, covered with 25 mm (1.0 in) of fiberglass blanket and 14 gauge 304L stainless steel sheet. The nominal size 89-mm (3.5-in) schedule 40 304L connection for the coils extends to the top of the vessel, to facilitate remote connection to the cooling water and steam supply.

The CFMT is U-stamped per American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section VIII, Division I.

The CFMT is used to prepare a well mixed melter feed by agitating and concentrating the vessel contents for a batch cycle time compatible with the feed rate. Concentration of contents is accomplished by heat exchangers consisting of a steam coil jacket and bottom heating coil that together effect a slurry boiling temperature of 102°C to 110°C (216°F to 230°F). A Closed Loop Cooling Water (CLCW) system provides temperature control, as required. The CFMT is designed for an evaporation rate of 1.13 m^3/hr (300 gal/hr) and cool-down to 40°C (104°F) in 8 hours. The tank agitator is capable of resuspending solids in the event the agitator has been shut off for a period of time (e.g., 72 hours or longer).

A demister unit is located in the outlet flange (nozzle) from the CFMT to the vent header (see Figure C.6.1.3-1). The unit is designed to return moisture entrained in the vessel ventilation air back to the CFMT vessel. The demister unit has a 304L stainless steel housing and contains a York style 644 demister pad (152 mm [6 in] thick by 429 mm [16.875 in] in diameter) fabricated of Hastelloy C-22. Lines are provided to measure pressure differential across the mesh pad and to spray chemicals (anticipated to normally be demineralized water) to wash accumulated slurry from the mesh back into the CFMT.

Negative pressure in the CFMT (compared to Vitrification Cell pressure) is maintained by means of the Vessel Vent Header during the two primary operating modes, namely, boiling and non-boiling.

The CFMT seal pot is the vessel's pressure relief and the overflow point. The design provides a 508-mm (20-in) water seal. Flow through the seal pot goes to the Waste Header (described in Section C.6.3.1.1) which routes the liquid through the concrete shielded Transfer Trench back to Tank 8D-4. Should the CFMT overflow into the seal pot, the increased specific gravity of the slurry would increase the seal pressure up to approximately 762 mm (30 in) water column (WC).

The CFMT is operated on a batch cycle, with the timing of that cycle dependent upon the glass production rate, the degree of concentration required, and the sampling and/or analysis times. The mixed HLW slurry (8D-2, THOREX, and zeolite) is received from Tank 8D-2 and added to a heel from the previous batch. There can also be a recycle transfer from the SBS.

Typical transfers from 8D-2 are on the order of 14 m^3 (3,698 gal) (nominal) of mixed slurry, with a solids content on the order of 15 percent. The mixture of heel, SBS recycle, and 8D-2 HLW slurry, essentially the full working volume of the CFMT, about 19 m^3 (5,019 gal), is then boiled down to a maximum concentration before the addition of glass formers. Glass formers are added as a 60% solids slurry. The glass formers weight fraction is approximately 70 to 80% of the total solids weight; hence, the final slurry composition is less sensitive to the HLW feed components.

There can be considerable flexibility in the batch size, cycle times, and concentration ratios. The CFMT batch cycle varies from approximately 100 to 500 hours, driven primarily by analytical requirements and concentration (evaporation) requirements of the batch. The HLW feed slurry content is dependent upon the inventory make-up of the large volume Tank 8D-2 at the time of feed transfer. Section C.6.2.1 describes the CFMT feed preparation steps. In the concentration phase, the slurry mixture is evaporated until the solids concentration (soluble and suspended slurry in the feed) is increased to approximately 40 to 50 percent by weight. Steam from the CFMT flows to the Vessel Vent condenser, from which condensate flows by gravity to Tank 8D-3. The contents of this tank are sampled and analyzed and, based on the analysis and operational need for flushing solutions, recycled back to Tank 8D-1, Tank 8D-2, or sent to the Liquid Waste Treatment System (LWTS) for processing. The operations of the LWTS are discussed in other DOE-approved WVDP safety documentation.

C.6.1.3.2 Melter Feed Hold Tank

The MFHT is used as a surge tank to meter feed to the melter. Figure C.6.1.3.2-1 is an engineering drawing of the MFHT. The concentrated mixture from the CFMT is transferred, as a batch, to the MFHT, from which it is fed to the SFCM. The MFHT has approximately the same working volume as the CFMT, 19 m^3 (5,019 gal), which is sufficient to provide greater than 100 hours of feed to the SFCM. A mechanical agitator maintains the feed in a well mixed condition. The agitator is capable of resuspending solids in the event the agitator has been shut off for a period of time.

All MFHT vessel components are made of 304L stainless steel, with a corrosion allowance of 0.4 mm (0.016 in). The vessel has a design life of 350 batches. General corrosion is anticipated to be less than 2.5E-03 mm (1.0E-04 in) per year. Localized pitting or crevice corrosion will not occur under expected process conditions. The largest diameter flange is for the agitator, at 965 mm (38 in). Flange gaskets are Viton attached to a 304L stainless steel carrier. Replaceable components, such as jumpers, are also fabricated from 304L stainless steel. The jumper used to transfer slurry from the CFMT to the MFHT has a remotely operable spoolpiece. The spoolpiece can be positioned to prevent slurry flow when desired.

A demister unit is located in the outlet flange (nozzle) from the MFHT to the vent header (see Figure C.6.1.3.2-1). The unit is designed to return moisture entrained in the vessel ventilation air back to the MFHT vessel. The demister unit has a 304L stainless steel housing and contains a York style 644 demister pad (152 mm [6in] thick by 429 mm [16.875 in] in diameter) fabricated of 304L stainless steel. Lines are provided to measure pressure differential across the mesh pad and to spray chemicals (anticipated to normally be demineralized water) to wash accumulated slurry from the mesh back into the MFHT.

The exterior of the MFHT is partially covered by a cooling jacket. The jacket has internal baffles that cause the water flow to spiral within a rectangular channel that is 275 mm (10.812 in) high and 44 mm (1.75 in) wide. The nominal size 76-mm (3-in) schedule 40 connection for the coils extends to the top of the vessel, to facilitate remote connection to the cooling water supply. The MFHT is U-stamped per ASME Boiler and Pressure Vessel Code Section VIII, Division I.

The MFHT seal pot is the vessel's pressure relief and the overflow point. The design provides a 508-mm (20-in) water seal. Should the MFHT overflow into the seal pot, the increased specific gravity of the slurry would increase the seal pressure up to approximately 762 mm (30 in) WC. Flow through the seal pot goes to the waste header. As with CFMT, negative pressure is maintained relative to the cell pressure by means of the Vessel Vent Header.

Cooling water is routed through the tank cooling equipment to remove heat resulting from the tank agitator and from the decay heat of the HLW slurry.

A feed system capable of controlling the flow to the melter at a rate of 15 to 200 L/hr (4.0 to 52.8 gal/hr) consists of an air-driven submerged pump that is remotely replaceable.

C.6.1.4 Slurry-Fed Ceramic Melter

The SFCM is the key piece of equipment in the vitrification process and operates on the same principle as many electrical melters in the commercial glass industry. Figure C.6.1.4-1 is a cutaway representation of the SFCM.

The function of the melter is to dry and melt the slurry that is fed to it, converting it to glass. The melter heating unit consists of three electrode plates in contact with the glass. Two of the three electrodes are located in the sides of the vessel. The third electrode is in the floor of the vessel. The melter vessel is cooled by the CLCW system for key refractory wall areas and by use of cooling air for electrodes. The electrode firing pattern for the melter is a regular sequence among all three electrodes, using silicon control rectifiers to control the pattern. The electrodes, fabricated from Inconel 690, draw approximately 120 kW during normal process operation. The weight of the SFCM is 43,000 kg (47.2 tons) including the molten glass, and its dimensions are 3 m x 2.4 m x 2 m high (10 ft x 8 ft x 6 ft high). The nominal volume of glass in the melter is 0.86 m^3 (227 gal).

Each of the three melter electrode conductors are introduced into the Vitrification Cell through a cell wall penetration. As shown in Figure C.6.1.4-2, the electrode assembly is enclosed in a metal shroud (called the Electrode Penetration Shroud). Utility air flows into this shroud and into the annular space between the shroud and the wall penetration to remove heat from the electrode assembly and wall area. This cooling air is exhausted into the cell environment.

The air flow rate to both the Penetration Shroud and to the Electrode Penetrations is alarmed for low flow on the Distributed Control System (DCS). If air flow is lost, the operator would reduce electrode power as necessary to keep the electrodes below their high temperature alarm. Automatic shutdown is not provided for loss of cooling air flow because instantaneous action is not required to prevent electrode or cell wall damage. Power to the electrodes is supplied by a silicon control rectifier, which is cooled by the CLCW system. If cooling water is lost to the rectifier, feed to the SFCM is terminated. If power to the electrodes must be maintained, utility water can be aligned to provide the cooling function.

The feed slurry is pumped into the SFCM through the waste input feed nozzle (see Figure C.6.1.4-1). The feed has a density of approximately 1.3 to 1.5 g/cm^3 (81.2 to 93.6 lb/ft^3) and is input into the melter at a rate of 15 to 200 L/hr (4.0 to 52.8 gal/hr). The glass-forming elements are principally silicon and boron to which sodium and small amounts of glass modifiers may be added. The glass formers in combination with the well mixed waste form a borosilicate glass that meets specifications for HLW disposal, as required in *Waste Acceptance Product Specifications* (WAPs) established by the DOE Office of Environmental and Waste Management (U.S. Department of Energy 1993). The glass formers are added as oxides or hydroxides of their particular species. From 70 to 90% of the surface of the molten glass in the SFCM is normally covered with a crust of dried and calcined waste solids, called the cold cap.

The molten glass is contained within a cavity made up of a highly corrosion-resistant refractory (Monofrax[R] K-3 and E). Zirmul refractory backs up the Monofrax refractories, and Alfrax 66 castable refractory surrounds the Zirmul refractory. Fiberfrax fiberboard backs up the Alfrax because it is a better insulator (but less suitable for corrosion resistance) than the other refractory materials. The entire refractory assembly is encased in a highly corrosion-resistant Inconel shell. The molten glass mixes in the melter primarily by natural convection currents from heat input. The metal shell of the melter is cooled by a water jacket on the walls and the bottom of the vessel.

The bulk glass is heated and normally maintained in the melting cavity at a temperature between 1,100°C and 1,200°C (2,012°F and 2,192°F). The molten glass exits the SFCM at a nominal flow of 30 kg/hr (66 lb/hr) (and at a maximum rate of 50 kg/hr [110 lb/hr] for short periods of time) through the throat of the discharge duct located near the bottom of the vessel as shown in Figure C.6.1.4-1. To exit, molten glass rises up a tunnel, assisted by an air lift, into an overflow chamber, where it flows down a trough and drops into a receiving canister.

During a glass transfer, metered utility air (calibrated range of 0 to 0.057 m^3/min [0 to 2 ft^3/min]) is bubbled into the overflow chamber, displacing glass and raising the level of the melt in the passage, causing it to flow from the melter into the product canister. A platinum pipe is used to bubble air into the glass. Platinum was chosen as a material that will not require replacement during the life of the melter. When the canister has been filled, the glass flow can be stopped by discontinuing air flow to the air lift. The overflow chamber is heated by silicon carbide radiant heaters to keep the glass molten.

The melter has two discharge channels, one for primary service and an installed spare. The discharge channel silicon-carbide heaters can be remotely removed and replaced, as necessary. Acceptable process parameters for the vitrification process operations, including the feed make-up operations, were established during pilot plant tests using simulated non-radioactive waste. The test data from these pilot plant activities are referred to as the FACTS (Functional and Checkout Testing of Systems) runs. The life expectancy of the heating elements was established during the FACTS runs to be about ten months. Canister handling (including level measurement) is addressed in Section C.6.4.1.

The molten glass is poured from the melter into HLW canisters made of 304L stainless steel (empty weight approximately 183 kg [403 lb]). The canisters have a minimum wall thickness of 3.4 mm (0.13 in), an outside diameter of 0.61 m (2.0 ft), an overall height of 3.0 m (9.8 ft), and a throat opening of 0.42 m (1.38 ft). They are designed to contain approximately 1,900 kg (4,189 lb) of glass at a 85 percent fill level (nominal fill level). The canisters are filled to a minimum of 80 percent full (see Section C.4.3.1 for basis) and a maximum of 100 percent full, before the lid is welded in place. The typical canister fill rate of 30 kg/hr (66 lb/hr) results in a normal canister fill time of approximately 63 hours (2.6 days). Thus, sufficient time is available for the operators to carefully assess the canister fill status and to shut it off without overfilling.

Melter off-gases collect in the area above the molten glass surface and are removed from that area through the off-gas vent (see Figure C.6.1.4-1). The melter cavity is maintained at a pressure of approximately -127 mm (-5.0 in) WC, induced through the Process Off-Gas system by the discharge blowers. The off-gas from the SFCM is composed primarily of steam, air, decomposition gases, aerosols, and volatile species. Melter off-gas is treated in the Off-Gas system before being discharged through the Main Plant stack.

A film cooler is located in the initial portion of the off-gas pipe. It consists of a louvered insert that supplies a cool air flow, approximately 4 m^3/min (141 ft^3/min), along the inner surface of the exhaust pipe. This serves two functions:

- It provides a boundary layer of clean air between the main stream of the off-gas and the inner surface of the pipe.
- It cools the off-gas to a temperature below the glass melting point, as the boundary layer mixes with the main stream, to minimize sticky deposits in the off-gas piping and to prevent sulfidation corrosion of the off-gas components.

A pneumatically operated brush is installed to clean the film cooler. The brush is operated at regular intervals to prevent sufficient buildup as to necessitate a more elaborate cleaning technique. The cleaner is operated by two pneumatic cylinders. Should pressure to the pneumatic cylinders be lost, the system is designed with two latches that engage to hold the cleaner out of the film cooler, and out of the plenum. If necessary, the brush is changed remotely and stored in the HLWIS. It is anticipated that changeout of the brush may not be necessary during the processing campaign. Used brushes would be disposed of at the end of the processing campaign, along with the removed process equipment and debris resulting from the decontamination and decommissioning activities.

Air is injected into the off-gas line near the melter through an air addition line to further cool the off-gas, minimize plugging, and assist with pressure control.

The melter was designed with restraints to provide stability during the design basis earthquake. Because cooling to the melter shell may be inoperable after a seismic event, the seismic restraints include slots to allow for thermal expansion as the temperature of the melter shell increases.

The melter vessel, refractory, and electrodes are designed with sufficient life expectancy to complete the vitrification campaign without replacement. Melter accessories which require maintenance can be remotely removed and replaced. Decontamination and decommissioning design provisions allow for remote removal of the melter from the Vitrification Cell. Removal of the vessel requires remote crane placement of a rail bridge over the pit containing the major process vessels and connection to the existing transfer cart rails.

During start-up operations, five radiant heaters are used to dry and cure the refractory. After sufficient cure time, the melter is slowly heated to approximately 1,100°C (2,012°F) and glass frit is added. Joule heating of the glass is initiated when the glass sufficiently covers the electrodes and the temperature reaches approximately 1,150°C (2,102°F). After joule heating is established, the radiant heaters are remotely removed from the melter and the system is configured for normal operation.

Provisions exist to remove the molten glass heel from the melter when the processing campaign is completed. The provisions can also be used to drain the melter in the event of a melter failure such as loss of both discharge troughs or accumulation of metallic precipitate. Draining of the melter is accomplished using an evacuated canister suction technique. The evacuated canister, used to remove the heel, is a closed canister equipped with a suction pipe that is sealed with a fused aluminum plug. A support cradle holds the canister above the melter while the suction pipe is positioned into the melter cavity by the cell crane and the filling operation is performed. The aluminum plug on the suction pipe melts in approximately 5 minutes and atmospheric pressure pushes the molten glass into the evacuated canister. The heel removal requires the use of two evacuated canisters.

The melter operation has the following operating modes during the processing campaign:

- Electrode power-melter feeding.
- Electrode power-standby (i.e., melter not feeding (idle)).
- Maintenance mode-hot, but with power off.

The normal operating mode of melter feeding has been discussed above. The other operating modes are briefly described below.

During idle mode periods, when the melter is not being fed with slurry from the MFHT, sufficient power is supplied to the melter electrodes to maintain a constant temperature in the molten glass. The glass is maintained at approximately 1,150°C (2,102°F) and the temperature of the plenum rises to a maximum temperature near that of the molten glass, as the evaporation and chemical reactions in the cold cap are completed.

Slurry feed to the melter is shut off whenever power to the electrodes is terminated to allow planned maintenance (such as thermowell replacement) or due to unplanned loss of electrical power. The melter electrodes can be restarted with no special provisions after a period of approximately 6 to 8 hours with no power. After the molten glass temperature has dropped below an approximate temperature of 900°C (1,652°F), the conductivity properties of the molten glass decrease and the restart process (discussed above) using radiant heaters must be performed to reheat the molten glass to approximately 1,000°C (1,832°F) before the melter electrodes are started again.

C.6.1.5 Canister Turntable

The canister turntable, shown in an isometric view in Figure C.6.1.5-1, is used to precisely position an empty canister under the melter pour spout for filling and then, after a canister is filled, rotate to a position from which the canister can be removed from the turntable. The turntable holds four canisters at a time and is designed for cooling the hot canister after filling. Canisters are placed in the turntable and removed by the remotely operated cell crane and canister grapple. The turntable can be disassembled by remote means in the event the turntable drive does not function properly. The drive motor and drive unit, seals and other parts on the turntable can be removed remotely for repair and replacement.

An overload current trip for the motor is provided to prevent damage to the system from binding or abnormal resistance of the turntable to rotation. An electrical interlock exists that prevents turntable rotation whenever a canister filling operation is in progress. This is accomplished by sensing for air-flow to the molten glass air-lift.

C.6.1.6 Closed-Loop Cooling Water System

Cooling water is provided to the CFMT, MFHT, SFCM, SBS, Vessel Vent condenser, and canister decontamination tank from the CLCW system. This system consists of a main circulation pump, an installed backup pump, a hold tank, and a heat exchanger located outside the Vitrification Cell. The system circulates water through a heat exchanger (that transfers heat to the Cooling Tower Water system), through the vitrification related components, and then returns it to the hold tank.

C.6.2 Process Chemistry

Chemistry-related considerations are of substantial concern throughout many of the vitrification process steps shown in Figure C.6-2 and described in Table C.6-1.

C.6.2.1 Melter Feed Preparation

The feed make-up process begins with the transfer of a quantity of dilute radioactive sludge slurry to the CFMT from Tank 8D-2. Once in the CFMT, the following main activities are performed:

- Dewater the feed to minimize extra load evaporation requirements in the melter.
- Add the appropriate quantities of glass forming chemicals to result in acceptable glass product.
- Add nitric acid to improve the slurry rheology so the feed can be processed at high rates - thought to be a function of the slurry pH, perhaps related to partial dissolution of $Fe(OH)_3$.
- Add sucrose to minimize foam generation in the melter.

Following the receipt of the slurry, the CFMT is heated to evaporate and concentrate the HLW slurry. Before concentration, samples of the concentrated tank slurry are taken. Through remote-handled equipment, the samples are dissolved and both Atomic Absorption (AA) and Inductively-Coupled Plasma (ICP) tests are performed on diluted samples. The mixture of glass formers, nitric acid, and other chemicals needed to meet specifications for melter feed are determined based upon the sample analysis results and the measured volume of the CFMT. These cold chemicals are measured and mixed in the Cold Chemical Building and pumped into the CFMT where the agitator stirs the mixture.

Acceptable element levels within the glass have been established based on FACTS data, established during pilot plant nonradioactive testing activities. Typical composition of aqueous melter feed slurry (after chemical additions and reactions in the CFMT) is shown in Nixon (May 1, 1995). Typical glass-forming chemical make-up is shown in Table C.6.2.1-1. No thorium, uranium, or calcium is added by the Cold Chemical Delivery System (CCDS), so the batches may be below target values for these species.

Typically more than 20 elements are analyzed and reported, although only 15 are included in the composition control. These 15 (Al, B, Ca, Fe, K, Li, Mg, Mn, Na, P, Si, Th, Ti, U, and Zr) typically account for more than 98% of the glass composition.

Four elements (Fe, K, P, and Th) are reviewed for their effect on batch size, before the amount of glass-forming compounds to be added to the CFMT is calculated. If any of these species are present above or below the desired level, the goal CFMT batch size is increased or decreased such that these species are within desired levels.

Following receipt and mixing of the glass forming chemicals, the CFMT is sampled and analyzed to verify the batch quality. Having already tested both the Cold Chemical Make-up Tank, and the CFMT before adding the cold chemicals, a simple element-by-element material balance is performed using the new CFMT sample results.

C.6.2.2 Vitrification

The melter feed slurry is introduced from the top of the melter and drops onto the crust of dried chemical solids known as the cold cap. Figure C.6.2.2-1 is a cutaway view of the melter indicating chemical reactions. As indicated in the figure, the heat of the cold cap causes boiling of the newly introduced slurry, evaporating water from it, and leaving the metallic salt and hydroxide residue that forms the cold cap. As the cold cap is heated, the residues react to form metal oxides and gaseous products such as H_2O and NO_2. The metal oxides equilibrate at the glass pool temperature (about 1,150°C [2,012°F]). Most of the chemical reactions occur following evaporation in either the cold cap or in the molten glass pool. The product of these reactions is molten glass, which is then poured into canisters.

Typical primary constituents of the finished glass composition are summarized in Table C.6.2.2-1. The FACTS runs performed with nonradiological feeds (including simulated waste) indicate acceptability of the process.

The temperature of the molten glass and the temperature of the off-gas in the melter plenum above the cold cap are the primary parameters used to establish the slurry feed rate to the melter from the MFHT. The temperature of the glass is kept relatively constant at approximately 1,150°C (2,102°F) during both idle and slurry feed conditions. The temperature of the plenum changes significantly with different feeding conditions, with normal conditions of approximately 1,100°C (2,102°F) at idle, varying to approximately 450°C (842°F) during normal slurry feeding operations.

The reactions listed below describe the chemistry thought to occur in the vitrification melter for the major constituents. Reactions of the smaller percentage components found in the glass may be found in Ross (April 14, 1988). Experiments have not been done to document their validity.

$2\ H_3BO_3 \rightarrow B_2O_3 + 3\ H_2O$

$2\ AlF_3 + 3\ Na_2O \rightarrow Al_2O_3 + 6\ NaF$

$2\ Al(OH)_3 \rightarrow Al_2O_3 + 3\ H_2O$

$2\ Fe(OH)_3 \rightarrow Fe_2O_3 + 3\ H_2O$

$2\ Fe(NO_3)_3 \rightarrow Fe_2O_3 + 6\ NO_2 + 3/2\ O_2$

$2\ FePO_4 \rightarrow Fe_2O_3 + P_2O_5$

$2\ K_2CrO_4 \rightarrow 2\ Cr_2O_3 + 2\ K_2O$

$2\ KMnO_4 \rightarrow K_2O + Mn_2O_3 + 2\ O_2$

$2\ KNO_3 \rightarrow K_2O + 2\ NO_2 + 1/2\ O_2$

$Si(NO_3)_4 \rightarrow SiO_2 + 4\ NO_2 + O_2$

$Th(OH)_4 \rightarrow ThO_2 + 2\ H_2O$

During normal feed preparation, nitric acid is added to the CFMT to reduce slurry viscosity, if needed. The "redox" state of the glass is adjusted by the addition of sugar (sucrose) as a reductant and nitric acid as an oxidant. Glass that is too oxidized releases gases as metal oxides from the cold cap melt into glass at a lower equilibrium oxidation state. These gases form foam which causes adverse effects in the melter such as inhibiting heat transfer from the molten glass to the melter plenum. Thus, the addition of sugar to the feed controls foam generation. Glass that is too reduced can result in reduction of the metal oxides in the glass to the point of precipitating spinels and sulfides. These precipitates, which may be conductive, could settle to the bottom of the melter and eventually short out the electrodes.

C.6.2.3 Melter Off-Gas

Off-gas from the SFCM is principally water, oxides of nitrogen (NO_x gases), CO/CO_2 (decomposition of carbonates and sugar), sulfur dioxide (SO_2), oxygen, and nitrogen. NO_x converters are present in the Ex-Cell Off-Gas system to destroy the acidic vapors so that no more than 1.9 kg/hr (4.2 lb/hr) per hour of NO_x is released to the atmosphere. The oxides of nitrogen are reacted with ammonia at an elevated temperature, in the presence of a catalyst, to produce harmless water vapor and nitrogen. The following reactions occur within the NO_x abatement equipment.

$2\ NO + O_2 \rightarrow 2\ NO_2$
$8\ NO_2 + 6\ NH_3 \rightarrow 7\ N_2O + 9\ H_2O$
$2\ N_2O \rightarrow 2\ N_2 + O_2$

These reactions are all exothermic. Therefore, the off-gas becomes hotter as it passes through the NO_x converter.

Except for I-131 and Rn-220, Table C.6.2.3-1 shows the maximum projected annual release and concentrations of radionuclides released from the process off-gas stack, after passing through the in-cell and ex-cell off-gas treatment and filtration equipment. I-131 and Rn-220 information shown in Table C.6.2.3-1 is derived from operational experience.

C.6.2.4 Properties of Glass Product

Based on the curie loading per canister (summarized in Table C.4.3.1-2), the nominal heat release is 340 watts/canister (a range of 300-390 watts/canister). Based on this expected energy release and physical properties as presented in Table C.6.2.4-1, a peak center line temperature of 45°C (113°F) and a surface temperature of 30°C (86°F) in an ambient air temperature of 25°C (77°F) is expected.

C.6.2.5 Key Process Parameters

The key process parameters for successful glass production are the maintenance of feed composition, feed flow rate and glass melter temperature. The large batch make-up philosophy provides sufficient spare (float) time to assure conformance to the concentration specifications. The WVDP test program produced nonradioactive glass using essentially identical equipment to that used for the radioactive production runs. Both the process and equipment have been demonstrated during these cold run campaigns. Approximately 160,000 kg (3.53E+05 lb) of simulated waste glass were produced in the FACTS runs (Carl, September 30, 1990) to establish operating procedures, controls, and equipment reliability for the radioactive production activities.

C.6.3 Off-Gas Treatment, Facility Vent, and Liquid Waste Systems

Effluent from the Off-Gas and Liquid Waste Systems must be considered to develop a proper mass balance for the vitrification process. Figure C.6-3 shows a vitrification process mass flow diagram.

C.6.3.1 Off-Gas System

Operation of the VF generates radioactively contaminated off-gas from the process tanks and vessels. The gas from all vessels except the SFCM is collected by the

Vessel Ventilation system. The Vessel Vent system off-gases are then merged with the off-gas from the SFCM for processing.

The Off-Gas System provides two primary services to the HLW vitrification process and the facility operators:

- Safe removal of process gases from the melter and other vessels.
- Collection of radioactively contaminated materials from the off-gases to assure radiation exposures are kept as low as reasonably achievable (ALARA).

Inputs to the Vessel Vent System are shown in Figure C.6.3.1-1. A flow diagram of the Off-Gas system is provided in Figure C.6.3.1-2. Figure C.6.1.2-1 shows the location of many of the in-cell Off-Gas system components, including the Vessel Vent Header, vessel vent condenser, High Efficiency Mist Eliminator (HEME), filter preheater, prefilter, and post heater. The SBS cannot be clearly seen in the figure, but is located between the CFMT and the Turntable. Brief descriptions of the primary Off-Gas system components are shown in Table C.6.3.1-1. These components are discussed in detail below.

The Vessel Ventilation and Off-Gas systems are designed to maintain approximately 127 mm (5 in) WC vacuum on vitrification process components while the SFCM is operating at a rate of about 45 kg/hr (99 lb/hr) and a HLW feed rate of 150 L/hr (39.6 gal/hr). The vent header is designed to accommodate a total of 45 m^3/min (1,589 ft^3/min) of gases and vapors.

The Off-Gas system originates with off-gas piping from the SFCM, as shown in Figure C.6.3.1-3. The Vessel Ventilation system merges with the SFCM off-gases immediately after the SBS treatment and mist eliminator components. The merged streams are then processed together through the remaining in-cell Off-Gas system.

Following in-cell processing and filtering, the gases are piped to the ex-cell Off-Gas system though an insulated duct in the concrete Off-Gas Trench. The ex-cell portion performs final HEPA filtering and NO_x removal before release to the Main Plant stack.

C.6.3.1.1 Vessel Vent Header

The Vessel Vent Header collects gases from all in-cell process vessels, except the SFCM. A major function of the Vessel Vent Header is to condense the steam produced by operation of the CFMT and entrained moisture from other process vessels and direct the condensate to Tank 8D-3, allowing only a reduced humidity from the Vessel Vent gases to enter the off-gas treatment equipment. This is accomplished by passing all Vessel Vent gases through the vent header condenser.

Condensate from the Vessel Vent Header condenser flows by gravity through a standpipe type weir (calibrated to give condensate flow from the condenser in gpm), to Tank 8D-3 for subsequent processing. The remaining gases and uncondensed vapors exiting the condenser are directed through a jumper and merged with the SFCM off-gas. A diaphragm-operated pressure control valve installed in the non-condensibles jumper controls the vacuum in the Vessel Vent Header. The pressure control valve's position is automatically modulated to maintain a target pressure (vacuum) based upon condenser shell side inlet pressure.

In the event that vacuum is lost in the SFCM, the melter gases and vapors would also be directed into the Vessel Vent Header to re-establish the vacuum in the melter.

The Vessel Vent Header condenser is designed to permit remote removal and replacement of the tube bundle, consistent with the remote maintenance philosophy applied for all in-cell equipment.

C.6.3.1.2 SFCM Off-Gas

The first step in treating the off-gas from the SFCM is to quench it from a temperature of 300°C to 400°C (572°F to 752°F) to below 45°C (113°F). This is accomplished by the melter film cooler and the SBS.

The SBS is a passive process mechanism that uses water to quench the off-gases and remove particulates. Off-gases are bubbled through water in a bed packed with ceramic spheres. Figure C.6.3.1.2-1 illustrates the gas flow through the SBS. The rising bubbles of off-gas cause the liquid to circulate up through the ceramic packing. This causes downward flow in the annular space outside the packed bed, as liquid from the outside annular space replaces the liquid that rises through the bed. The packing breaks larger bubbles into smaller ones to increase the gas-to-water contact surface, thereby increasing particulate removal and heat transfer efficiencies. The liquid circulation helps prevent a buildup of captured material in the bed by constantly washing the material away. As the off-gas cools, water vapor condenses, increasing the liquid water inventory in the mechanism. Excess water spills into the receiver, to maintain a constant liquid depth in the scrubber. Heat absorbed by the water from the off-gas is removed by the heat exchanger (cooling water jacket coils) as the water flows downward in the outside annular space. The scrubber solution containing particulates is removed from the off-gas stream and recycled back to the CFMT, where it is mixed with other wastes and glass formers before being fed to the melter.

A mist eliminator is located in the SBS off-gas exit nozzle flange and consists of a mesh pad in a housing. A jumper is present to provide demineralized water to flush the pad when the measured pressure differential across the mesh becomes excessive.

Although the SBS is not specifically designed to remove oxides of nitrogen, it does remove about 3% of the amount entering with the off-gas.

C.6.3.1.3 In-Cell Off-Gas Filtering

The gaseous effluents from the SBS and Vessel Ventilation system contain some particulates. Therefore, the off-gas is next filtered by one of two parallel and redundant HEME units and prefilter exhaust trains. The gases pass through one filter train and the other is a back-up.

Prior to entering the HEME, the off-gas may be heated in the HEME preheater to raise the temperature above the dewpoint of the off-gas. It is expected that the preheating option is not to be used routinely. The HEME collects and coalesces entrained liquid droplets and removes submicron particulates from the gas. It is 99.8% (w/w) efficient for liquid droplets 3 microns (1.2E-04 in) in diameter and larger. As solids accumulate in the HEME, the pressure drop across the filter increases. The HEME can be continuously washed with a water spray or washed as needed when the pressure drop increases. Wash water is recycled back to the SBS and thus periodically transferred to the CFMT. The HEME filter element is remotely replaceable.

After passing through the HEME, the gases pass through a preheater to raise the temperature sufficiently above its dew point to insure that no moisture is present to condense on the prefilter assembly HEPA filters. The prefilter assembly captures dry particulates to retain radioactive contamination inside the Vitrification Cell and thus reduce the amount of radioactive material reaching the ex-cell Off-Gas Treatment equipment. Each prefilter housing contains two HEPA filters in series. Both parallel HEPA filter assemblies are remotely replaceable.

After the off-gas passes through the in-cell HEPA prefilters, the stream consists primarily of air, water vapor, and some NO_x. The gas is then routed to an insulated duct (254-mm [10-in] diameter pipe) in the Off-Gas Trench to the 01-14 Building.

C.6.3.1.4 Ex-Cell Off-Gas Treatment and Filtering

The Ex-Cell Off-Gas system, shown schematically in Figure C.6.3.1.4-1, provides final HEPA filtration of any radioactive particulates not captured by the in-cell system. The ex-cell processes include moisture removal, reheating, HEPA filtration, and catalytic NO_x destruction. Ex-cell Off-Gas system features are expounded in Section C.5.2.7.4.

The Ex-Cell Off-Gas system is operated from the VF Control Room. Instrument signals are directed into a "Micon" cabinet located in the Instrument Room. The Micon is energized from the uninterruptable power supply. The output signals from the Micon cabinet are tied into the DCS located in the VF Control Room.

Items of equipment located within the 01-14 Building are designed for remote manual switch-over. These include the off-gas reheater, HEPA filters, filter housings, converter preheaters, and catalytic converters.

The insulation on the duct and an entrainment separator within the duct are used to minimize and remove condensate from the off-gas enroute from the Vitrification Cell to the 01-14 Building. Liquid accumulated in the entrainment separator is accumulated in a condensate tank for subsequent transfer to the south sump of the Vitrification Cell. Liquid in the south sump is cycled back to Tank 8D-4 via the Waste Header system.

The entrainment separator employs baffles to eliminate maintenance requirements. It is located at the low point in the duct, so that the entrainment separator drain serves to drain the entire duct.

Design scoping calculations were performed to determine the potential for and impact of collection of off-gas stream radionuclides in the ex-cell off-gas piping and treatment equipment (Vance October 12, 1994). The most significant points of concentration are expected to be the off-gas HEPA filters and the NO_x abatement system catalyst bed. Evaluation shows that the expected dose rate on the catalyst bed, after one year of operation, is less than 7 mrem/hr (0.07 mSv/hr) at 610 mm (2 ft). The most significant collected nuclides are expected to be 98% I-129 and 2% Cs-137. After one year of operation it is estimated that the catalyst bed will have a maximum of 0.36 Ci of I-129 and 0.0076 Ci of Cs-137, with the majority of the radiation exposure dose coming from the Cs-137.

C.6.3.1.5 Final Off-Gas Reheating and Filtration

Following entrainment separation, the gas is routed through reheaters, located inside the 01 cell of the 01-14 Building, to raise the dewpoint of the off-gas before final HEPA filtration. Electrical energy delivery to the reheater is modulated, based on an off-gas temperature measurement downstream from the reheaters, to maintain a preset temperature. The reheater trains are arranged and valved for remote manual switch-over, should one reheater train become unable to maintain the desired temperature.

Each of two parallel filter trains contain two HEPA filter units connected in series. The gases pass through one HEPA filter train, and the other is a back-up. The differential pressure across each unit is continuously monitored. Should the pressure drop across a filter become excessive, the installed backup prefilter train would be automatically valved into service. The HEPA elements are changed by a bag-out/bag-in procedure, followed by in-situ aerosol testing to confirm the integrity and filtering efficiency of the newly installed filter element and seals.

Following filtration, the off-gases pass through one of three redundant positive-displacement off-gas blowers installed in parallel. One blower operates and the others are back-ups. The blower provides the motive force to maintain all upstream vitrification equipment under a slight negative pressure for purposes of contamination control. The blower also provides the motive force to discharge the treated off-gases to the Main Plant stack for release to the atmosphere. An air in-bleed valve is located in the duct leading to the blowers to control the vacuum at the blower inlet. A pressure (vacuum) measurement at the blower suction is used as the basis for modulating the position of the control valve in the in-bleed line. The pressure (vacuum) set point is established at a value that ensures that the overall system can provide the necessary vacuum in the melter and Vessel Vent Header.

C.6.3.1.6 NO_x Abatement

From the blower, the off-gases pass through the NO_x abatement equipment. The purpose of this equipment is to destroy oxides of nitrogen to allow the off-gas discharge to meet or exceed requirements of the WVDP discharge permit from the New York State Department of Environmental Conservation. This is done by selective catalytic reduction of the NO_x gases with ammonia to produce harmless water vapor, nitrogen, and oxygen.

The NO_x destruction equipment includes parallel trains (one in service and the other a back-up) of off-gas preheaters, an ammonia (NH_3) supply system, and a catalytic converter. The preheaters increase the off-gas temperature to promote the desired reaction, the ammonia supply system provides the necessary reactant, and the catalytic converter accelerates the desired reaction.

A NO_x analyzer on the duct leading toward the NO_x abatement equipment establishes the amount of NO_x approaching the converters. This information is used as the basis for modulating the amount of ammonia reactant to be introduced into the duct immediately upstream from the catalytic converter.

Two parallel identical preheater trains (one in service and the other a back-up) are connected inside the 01 cell immediately upstream from the converters. Each preheater train consists of two heating elements in series. The reason for the two heating elements is to provide the residence time required to achieve the desired increase in off-gas temperature. Electrical energy delivery is modulated based on an off-gas temperature measurement downstream from the preheaters to maintain a preset temperature. The parallel trains are arranged and valved for remote manual switch-over, should one train become unable to maintain the desired temperature.

The ammonia supply system consists of an ammonia storage tank and dual ammonia vaporizers and mass flow control apparatus (for in service units and back-ups). The ammonia storage tank is located outside the 01-14 Building and is designed to receive periodic liquid anhydrous ammonia from delivery trucks. Liquid ammonia is gravity-fed from the bottom of the ammonia storage tank to the vaporizer, which is positioned near the bottom of the storage tank. The heated vapor from the vaporizer is routed to the upper portion of the ammonia storage tank. Vaporized ammonia is drawn from the vapor space at the top of the ammonia storage tank, and is routed to a pressure reducing, mass flow control apparatus. Where the ammonia feed line is outside the building and thus exposed to weather, it is insulated and heat-traced. Either flow control train can deliver ammonia to the off-gas inlet of either NO_x converter.

Electrical energy delivery to the vaporizer is modulated based upon the pressure of the vaporized ammonia. Both vaporizer elements (the in service element and the back-up) are normally submerged in the liquid ammonia, so that changing from one vaporizer to the other requires nothing more than redirecting the electrical energy from one element to the other.

The catalytic converter is located inside the 01 cell. The efficiency of the operating catalyst bed is monitored by comparison of inlet and outlet NO_x concentrations. Should the catalyst bed in the converter in service lose efficiency, the back-up unit can be remotely valved into service.

A NO_x analyzer on the converter outlet monitors the amount of NO_x being directed to the stack to assure that the NO_x emissions do not exceed requirements of the WVDP discharge permit from the New York State Department of Environmental Conservation. An ammonia analyzer on the converter outlet monitors the amount of NH_3 being directed to the stack to assure that ammonia concentrations are sufficiently low to prevent the formation of ammonium nitrate.

C.6.3.1.7 Off-Gas Discharge Duct

After processing through the NO_x treatment system, the off-gas is routed through an insulated duct to the exhaust stack. The duct is insulated to maintain off-gases above their dewpoint.

C.6.3.2 Facility Ventilation Systems

All areas of the VF that have a potential for becoming contaminated are ventilated in a controlled manner to ensure confinement of radioactive materials. Pressure differentials are maintained between contamination control zones to ensure that air flow is from zones of less potential for contamination to zones of greater potential for contamination. Ventilation of the EDR and HLWIS is provided by the existing Main Plant Ventilation and Head End Ventilation systems. Ventilation systems are discussed in detail in Section C.5.4.1.

The Transfer Tunnel vents into either the Vitrification Building Ventilation system or existing Main Plant Ventilation system, depending on the positions (open or closed) of the shield doors separating the Vitrification Cell and the Transfer Tunnel, and separating the Transfer Tunnel and EDR. When both shield doors are closed, the Transfer Tunnel air vents into the Vitrification Building Ventilation system. This is also the case when the Vitrification Cell/Transfer Tunnel shield door is open and the Transfer Tunnel/EDR shield door is closed. However, when the Transfer Tunnel/EDR shield door is open and the Vitrification Cell/Transfer Tunnel shield door is closed, the Transfer Tunnel vents to the Main Plant Ventilation system.

C.6.3.3 Waste Header System

The Waste Header system receives liquid wastes from the CFMT, MFHT, SBS, and canister decontamination station, and Vitrification Cell sumps that collect any liquids spilled or directed on the cell floor. The necessary auxiliary equipment, such as sump steam jets, instrumentation, and service jumpers, are part of the system. A schematic of the system is provided in Figure C.6.3.3-1.

The only routine flow to the waste header is the intermittent transfer of the rinse water from the Canister Decontamination Station. The header accepts overflow from the CFMT and MFHT. It also accepts intentionally discharged solutions, on a non-routine as-needed basis, from the Canister Decontamination Station, the SBS receiver, the MFHT, the CFMT, and the Vitrification Cell sumps.

The Waste Header system is sized to accommodate the transfer of concentrated waste feed makeup slurry, by gravity flow, at a rate of 95 L/min (25 gpm). At this flow rate, the waste remains in the bottom half of the header with enough turbulence to prevent deposition of solids in the header piping. The header permits gravity flow of pure liquids, such as water, at rates up to 127 L/min (33 gpm).

Pressurization of the header could result in back-up of wastes into various locations. To prevent such pressurization, flow into the header is limited. These limitations include the jets listed below:

- North Sump to Waste Header Jet
- South Sump A to Waste Header Jet

- South Sump B to Waste Header Jet
- Canister Decontamination Station to Waste Header Jet
- MFHT to Waste Header Jet
- SBS to Waste Header Jet
- SBS to CFMT Jet
- CFMT to MFHT Jet
- MFHT to CFMT Jet.

The Waste Header system is vented to the Vessel Vent Header to maintain the Waste Header system under a slight vacuum. A restrictive orifice in the jumper to the Vessel Vent Header protects the header from excessive air flow, and from a transfer of contaminated liquids or slurries in the event of a momentary, unplanned pressurization of the Liquid Waste Header system.

The Vitrification Cell contains three sumps to collect and allow transfer of spilled liquids from the cell. The north sump collects liquids and slurries from the Vitrification Cell pit. It is 254 millimeters (10 in) in diameter and 406 millimeters (16 in) deep, and has a capacity of 20 L (5 gal). It is lined with stainless steel. The steam jet used to evacuate the contents of the north sump to the Waste Header system is rated at 95 L/min (25 gpm). The suction line is covered by a 6.4-mm (0.25-in) screen mesh. The jumper used to provide level detection in the north sump extends to 12.7 mm (0.5 in) from the bottom of the sump, and includes a spare level tap that extends close to the bottom of the sump.

The south sump-A and the south sump-B collect liquids from the Vitrification Cell apron drains, Transfer Tunnel drains, Crane Maintenance Room (CMR) drains, Secondary Filter Room (SFR) sump, and Off-Gas Trench sump. The two sumps are 1.1 m (3.5 ft) by 1.2 m (4 ft) by 1.8 m (6 ft) deep, and each has a capacity of 2.38 m^3 (628 gal). They are lined with stainless steel and covered by a removable plate. Each has a jet used to empty the sump to the Waste Header system at a rate of 95 L/min (25 gpm). The suction line is covered by a 6.4-mm (0.25-in) screen mesh. Each jet discharge is equipped with a check valve to prevent back-flow of liquid waste into the sump, should the liquid waste header become pressurized. Both sumps are equipped with level detection. Sump-A also has specific gravity detection.

Cell sump design features are expounded in Section C.5.7.

C.6.4 Mechanical Process Systems

To achieve the vitrification process as presented in Figures C.6-3 and C.6-4, various mechanical systems are needed.

C.6.4.1 Canister Handling

Empty stainless steel canisters, 0.61 m (2.0 ft) in diameter and 3 m (9.8 ft) high and weighing approximately 183 kg (403 lb) each, are brought into the Vitrification Cell from the EDR by a remotely operated transfer cart, which holds up to four canisters. Based on operating experience, finished product canisters, filled with vitrified glass, weigh approximately 2,248 kg (4,956 lb) (92% full) on average.

Canisters are moved within the Vitrification Cell by means of a process crane with a grapple attachment that can lift a canister by its upper flange. The crane lifts the canister and places it onto the turntable through a port in the turntable superstructure.

Prior to introduction to the Vitrification Cell, each empty waste canister is labeled with a unique, five character, alphanumeric identification code. The identification code is located in two places on the canister: one on the top shoulder of the canister (visible from above the canister); and the other on the side of the canister about 600 mm (23.6 in) from the top. The label characters are inscribed on the canisters as weld beads using a 308L austenitic stainless steel welding rod and are at least 32.5 mm (1.3 in) high. Each canister is tracked and identified by its identification code in process logs, used to record the in-cell processing activities.

The canister turntable operating functions are:

- To position an empty canister under one of the two melter discharge spouts.
- To position a filled canister at the access port where it can be removed from the turntable and replaced with an empty canister.

The turntable/melter interface is designed to allow alignment, coupling, and decoupling of the turntable/canisters without shutdown of the melter. The instrumentation and controls in the canister turntable provide measurement of temperature, pressure, and glass level.

Independent and redundant methods are utilized to ensure canister position beneath the melter overflow. These are the following:

- Alignment of marks, on the rotating and stationary parts of the turntable, viewed by the in-cell CCTV.

- Position, viewed by the in-cell CCTV.

Process control requires remote indication of canister glass level. Level determination in the canister can be accomplished by the following independent approaches:

- Infrared Level Detection System (ILDS), using an infrared sensitive camera monitoring the canister exterior.

- Melter inventory change, including change in MFHT level, integrated feed rate to the melter, and glass level change in the melter.

- Visible detection by the glass pour viewing system. This includes both lack of glass pouring at times when airlift is not demanded, and detection of emitted light as glass pouring is in progress.

At least two (any two) independent methods of level detection are necessary before airlift operation for filling the canister is allowed.

The primary remote indication of canister fill height is by means of the ILDS. The ILDS consists of an imaging radiometer (essentially an infrared sensitive camera) with a wide angle (approximately 80° of view) lens. The signal from the camera is conditioned to display a colorized isotherm computer image in the VF Control Room that shows the glass level of the entire canister as it is filled. This method enables the VF Control Room operator to determine the glass level to approximately ±25.4 mm (1.0 in) of the canister height.

In addition, a periodic calculation determines material balance change. This information is used as an independent check on the other measurements. Two basic measurements are used in the mass balance calculation: The change in volume of the melter and the change in the volume of the MFHT. These two measurements are used to calculate the amount of molten glass transferred to the canister. Variations in the density of the feed slurry and variances of the amount of void space within the glass canister impact the accuracy of this method of predicting canister fill. During full scale cold operations, it was demonstrated that material balance measurements resulted in reasonably accurate (± 10%) glass volume/weight predictions.

When the canister is filled, the air lift in the melter discharge channel is shut off, preventing additional glass discharge. The turntable is then rotated to place an empty canister under the pour spout. To remove a canister from the turntable, the turntable access load-in load-out port cover assembly is removed and placed on a storage location provided on the turntable. The load-in load-out port cover assembly includes a flange so that it can be moved by the canister grapple.

An eight-canister storage rack is located in the pit south of the turntable. The rack can store empty canisters, filled canisters, welded canisters, and decontaminated canisters, or any combination thereof. A four-canister handling cycle is preferred, in which four empty canisters are moved into the cell on the transfer cart and exchanged, one canister at a time, for canisters that have been filled, welded, and decontaminated, and are thus ready for interim storage.

Filled canisters are moved to the storage rack or directly to the welding station. If a canister is stored in the rack prior to having its lid welded in place, a temporary lid is placed over the canister fill opening using the cell crane and a remote handling attachment. The cover is basically a circular plate, with provisions for remote handling, to keep extraneous material (such as crane oil and grease) from falling in the canister opening.

The Canister Welding Station is located at the east wall of the Vitrification Cell, as shown in Figure C.6.1.2-1, immediately below one of the cell shielded viewing windows. It is designed to remotely place and weld the lids on the filled product canisters. The equipment includes a work bench which can hold two canisters, a weld head, and other specialized tools for operations such as lifting the canister lid and repairing defective welds. Remote handling capability is provided by the remote manipulators of the cell window and a 230 kg (500 lb) capacity jib crane with a motorized trolley and carriage. The in-cell service cranes and associated canister handling grapples and tools also interface with the station when placing canisters in the holding stations.

CCTVs are mounted above the workbench to provide detailed views of welding operations. The cameras may be controlled from the VF Control Room or at the local station. All other welding controls are located at the local station. As much of the electrical/electronic equipment as possible is located outside the cell to protect personnel and equipment from radiation and to provide easy maintenance access to the equipment. The in-cell welding equipment can be repaired remotely, if necessary.

The canister welding system uses autogenous Pulsed Gas Tungsten Arc Welding (GTAW), also known as the pulsed tungsten inert gas (TIG) process. An inert commercial quality welding cover gas of 75% helium and 25% argon is used to protect the molten pool from oxidation and contamination during the welding process. The shielding gas is piped from two banks of three bottles located on a pad outside the Vitrification Building. The weld head is controlled by computer programs and the important welding parameters are monitored and recorded as the weld is performed.

Surveillance and visual inspection of the welding process are accomplished by observation through the shielded window and utilizing the CCTV cameras mounted above the workbench. The completed weld is visually inspected by a WVNS Quality Assurance Certified Welding Inspector. Acceptance is based on 1) Examination and determination that the recorded weld parameters are within acceptable limits and 2) Visual inspection of the weld passes.

After the lid welding is completed, the canister is moved to the decontamination station or to the storage rack, awaiting the availability of the decontamination station. After decontamination, the canister is normally moved with the crane grapple to the eight-canister storage rack (awaiting availability of the transfer cart) or directly to the four-canister transfer cart for movement through the Transfer Tunnel to the HLWIS for storage.

During operations, canisters are not placed in locations other than the turntable, the in-cell storage rack, the weld station, the decontamination station, or the interim storage racks in the HLWIS, or on the transfer cart, the process crane, or the HLWIS 16-ton crane using the canister grapple. Additionally, empty canisters are stored in the EDR as required. The EDR crane is not used to handle filled canisters due to its lack of recovery capability.

The Canister Decontamination Station is shown in Figure C.6.4.1-1. The components consist of: 1) A chemical feed subsystem (blending of nitric acid hold tank and ceric nitrate container (Ce^{+4}), 2) A titanium decontamination tank with bolted lid (for placement of the welded HLW canister), and 3) Titanium neutralization tank (for storage of decontamination solution after the decontamination cycle). The canister is positioned inside the decontamination tank, the lid secured, the solution is gravity fed to the tank, heated, agitated by sparger air, and processed for approximately six hours. Next, the fluid is transferred to the neutralization tank for eventual transfer to the SBS and, finally, the CFMT. The decontamination tank lid is positioned to allow the canister to be removed, sampled, and moved to the HLWIS or to a temporary storage location within the cell.

After decontamination has been completed, the canisters are placed in the four-canister transfer cart and moved through the Transfer Tunnel to the HLWIS. In the HLWIS, the canisters are stored in a storage rack structure mounted on top of a metal subfloor. The metal storage rack is designed to allow canisters to be stacked two high as shown in Figure C.6.4.1-2. The rack is loaded, utilizing the crane and grapple attachment. The bottom canister is put in place and then the upper canister is set on top of the bottom canister. The rack provides the necessary support to keep the canisters from falling over. Storage space in the HLWIS is provided for failed process equipment prior to decontamination, repair, and/or disposal.

All the above operations are controlled from direct observation through the shielding windows to the cells or from CCTV cameras within the cells.

The VF Load-In Building, shown in Figures C.6.4.1-3 and C.6.4.1-4, is designed to utilize the EDR as the primary access for moving canisters and replacement equipment into the Vitrification Cell or HLWIS. The Load-In Building provides for the off-loading of containers filled with canisters from a tractor trailer rig. Work areas are sufficient to allow for the removal of one shipping container from its transporter, the removal of the canisters from the container, receipt inspection, and storage of canisters to prepare them for the scheduled movement into the EDR. Material handling equipment provides for the movement of canisters into the EDR where they can be accessed by the EDR bridge crane for placement onto the transfer cart. Empty canisters are stored and secured outside of the EDR but within the weather enclosure for canister off-loading.

Except for the common use of the transfer cart, which has the function of transporting filled canisters through the EDR to the HLWIS, handling of radioactive materials is not part of the load-in function. In the event a piece of contaminated equipment needs to be replaced, the load-in function is used to move in the replacement equipment.

Contamination control is accomplished by balancing air flows from external sources and directing this air into the EDR when any exterior air passage is opened. To the extent possible ALARA concepts are being accomplished in the EDR, HLWIS, and the Vitrification Cell by using remote techniques.

C.6.4.2 Cell Cranes

The Vitrification Cell process crane is a twin 4.08-MT (4.5-ton) hoist/trolley mounted on a bridge. The twin hoists are positioned 813 mm (32 in) from each other on a turntable that allows the hoists to rotate 359 degrees. This allows either hoist to reach closer to the Vitrification Cell wall than would be possible with only a single hoist and also makes load orientation possible. In its normal configuration, the process crane has a canister grapple and an impact wrench linked from a hook. A remote manipulator-operated release mechanism is used to remove the impact wrench and the grapple from the hoist.

A back-up Vitrification Cell crane is also provided on a bridge identical to that of the process crane. The hoist/trolley on the back-up bridge has a 22.68-MT (25-ton) capacity. This capacity would be required only for major equipment change-outs or final decommissioning. The back-up crane is normally stored in the CMR on the same runway rail system used by the process crane.

In the event that the process crane fails, a failed hoist recovery module is available to lower suspended loads present on the crane hoist when the failure occurred. This module, which is situated on the back-up crane bridge, would be maneuvered to couple with the inoperational crane and lower and unload the stranded load on the process crane. The defective process crane would then be towed back to the CMR by means of towing latches on the back-up crane for repair.

Power and control for both cranes are provided by cable carrier systems that originate in the CMR. Portable operator control stations are located throughout the Operating Corridor at various shielded viewing windows. The control system includes "soft" start on all motions to avoid movement shock. Bridge and trolley drives have rubber-cushioned shaft-mounted gearboxes to further reduce shock. All motions on the cranes are two-speed and are relatively slow compared to movement of non-remote cranes to reduce the possibility of lifting mishaps. The crane motion speeds are given in Table C.6.4.2-1.

The EDR 18.14-MT (20-ton) crane is used to load empty canisters into the transfer cart. The crane has two 9.07-MT (10-ton) hoist trolleys mounted on a common set of girders. Crane motion speeds are given in Table C.6.4.2-1. The crane is controlled by a control pendant at the EDR window. All power and control is supplied by festoons. The contactors are outside the EDR in the EDR viewing aisle.

The HLWIS 14.51-MT (16-ton) crane is used to remove canisters from the transfer cart and place them onto the interim storage racks. The crane has a 14.51-MT (16-ton) trolley/hoist on the south girders and a 1.81-MT (2-ton) auxiliary hoist on the north girders. Crane motion speeds are given in Table C.6.4.2-1. The crane is controlled by a portable control station from any of the HLWIS windows or from the Chemical Crane Room (CCR) window. The control system is multiplexed, with motor contactors mounted on the bridge. Redundant programmable logic controllers (PLCs) are mounted above shielding blocks to increase reliability. PLC life is maximized by storing the crane in the CCR when not in use. The 14.51-MT (16-ton) hoist has redundant wiring that bypasses the entire control system and allows lowering of loads in the event of a control system failure.

In the event of a total crane cable reel or hoist motor/mechanical failure, a secondary "load-lowering module" is mounted between the HLWIS 14.51-MT (16-ton) hoist and the grapple. This module would allow the power manipulator bridge to be used to lower a canister to allow bridge retrieval. A towing mechanism is installed on the manipulator bridge so that a towing cable from a winch mounted on the CCR platform can be connected to the 14.51-MT (16-ton) bridge. The bridge can thus be pulled back to CCR for repair behind the CCR/HLWIS shield door.

C.6.4.3 Crane Maintenance Room

A shielded CMR is provided for parking the Vitrification Cell crane for decontamination and subsequent hands-on maintenance. Hatches are provided in the roof of the CMR so that crane, trolleys, and components can be removed. A shielded viewing window with remote manipulators (ports only, no plans to install manipulators) is also provided. Manipulator decontamination and repair is performed using the existing facilities in the Main Plant.

C.6.4.4 Canister Grapple

The canister grapple, shown in Figure C.6.4.4-1, is a gravity-actuated indexing mechanism that requires two complete set-down cycles to disengage the three lifting hooks. The design capacity of the grapple is over twice the maximum filled canister weight. An indicating system is provided on the grapple to give the operator status on the indexing mechanism. A remote manipulator-operated release mechanism is provided to allow canister removal in the event of failure of the indexing mechanism. The grapple also serves as a temporary cover during handling to keep foreign material out of the canisters.

Temporary covers are used for prolonged storage of canisters within the Vitrification Cell. The design of the cover allows the grapple to handle canisters with the cover in place.

C.6.4.5 Transfer Cart

A battery-powered radio-controlled transfer cart is used to move empty canisters into the Vitrification Cell from the EDR and move filled canisters to the HLWIS. The cart can be controlled from either the north viewing window of the Vitrification Cell or from the north window of HLWIS.

The transfer cart is normally stored at the battery charging station, located in a low-radiation area in the EDR to minimize total integrated dose to the cart control system. Four antennas are provided to ensure line-of-sight control transmission at all times. The cart has two antennas with a diversity detection system that continually checks signal strength and uses the antenna with the highest signal strength. The dual antennas assure continuous control even if signal nulls occur due to multi-path reception from the signal bouncing on stainless steel cell liners.

The transfer cart has four independent drive trains, any one of which is sufficient to drive the cart. The cart travels at approximately 4.6 m/min (15 ft/min). The control/battery enclosure can be replaced with a spare using an overhead crane in the EDR. In the event of a total cart failure, a previously existing tethered cart is available in the EDR to push or retrieve the failed cart. A removable canister rack holds four canisters in the center of the cart, approximately 102 mm (4 in) above the transfer cart rails.

C.6.4.6 Transfer Tunnel Shielding Doors

The shield doors are operated from control stations at the north viewing window of the Vitrification Cell or from the north window of the HLWIS. There are two Transfer Tunnel related doors: a 330-mm (13-in) thick steel door at the Vitrification Cell-Transfer Tunnel interface opens to the east, and, at the EDR-Transfer Tunnel interface, a 51-mm (2-in) thick steel twin-leaf ventilation control door opens to the north. A 1,219-mm (4-ft) thick concrete-filled shield door opens to the west between the EDR and HLWIS. The EDR-Transfer Tunnel door uses two linear actuators, whereas the other two doors along the transfer cart track open using ball screw drives.

The shield doors are interlocked with the transfer cart control system software to assure that doors are not operated when the transfer cart is moving and that the transfer cart cannot be moved when doors are moving. In addition, the cart controller only allows one door to be open (i.e., fully closed limit switch not tripped) at a time. This interlock can be overridden at the cart engineering station at the EDR viewing window in the event that more than one door needs to be opened to support a special remote operation such as cart retrieval.

C.6.5 Process Support Systems

C.6.5.1 Cold Chemical Building

The Cold Chemical Building is a 17.2 m x 10.4 m (56.5 ft x 34 ft) building located on the west side of the Vitrification Cell. It serves the following functions:

- Receipt and staging of bulk chemicals used to support the vitrification processing operations.
- Batch preparation of nonradioactive feed materials that are transferred to the Vitrification Cell for vitrification operations.
- Batch preparation of dilute nitric acid for routine filled canister decontamination.
- Batch preparation of decontamination solutions for equipment decontamination to accomplish system maintenance and for final VF decontamination and decommissioning.

The equipment in the Cold Chemical Building includes:

- 3 slurry mix tanks
- 3 solution preparation tanks
- 2 day tanks (nitric acid and caustic soda)
- 1 drain tank for waste collection
- 2 material delivery subsystems (solid and liquid)
- The tank ventilation subsystem.

This equipment is described in detail below. Figure C.6.5.1-1 is a Cold Chemical System flow diagram; more detailed Piping and Instrumentation Drawings (P&IDs) are shown in Figures C.6.5.1-2 through C.6.5.1-6. Major process vessels and their operating parameters are summarized in Table C.6.5.1-1.

Installed piping in the Cold Chemical Building that operates above 103 kPa (15 psi) conforms to ASME/ANSI B31.3. Major process vessels are designed and fabricated in accordance with the methods and practices of the ASME B/PV Code Section VIII, Division I, and provided with a "U" stamp (with the exception of the Drain Tank which was Government Furnished Equipment (GFE) and is not "U" stamped). The Drain Tank is not "U" stamped.

The Cold Chemical Building is unsupervised and unmanned during certain periods (e.g., while awaiting results of sample analysis). Should an alarm condition be indicated on the Cold Chemical system control panel (65-CP-01), it would be relayed to the VF Control Room as a general Cold Chemical system alarm. The alarm in the VF Control Room would sound if an alarm at the Cold Chemical system control panel went unacknowledged for more than a preset brief period of time.

C.6.5.1.1 Slurry Make-up and Transfer

Two types of slurries (i.e., glass formers and shim) are prepared in the Cold Chemical system, utilizing three slurry tanks (65-D-02, 65-D-03, and 65-D-04).

Slurries are prepared per recipe based on sampling the high level waste being vitrified or samples of glass produced. Solid and liquid ingredients are weighed and transferred into the mix tanks via a pneumatic transfer system (solids) and a steam jet transfer system (liquids). Concentrated nitric acid and caustic soda solutions are separately metered into the mix tanks from Tanks 65-D-05 and 65-D-06, respectively. Demineralized water used for flush and fill purposes is measured by batch control flow meters.

The slurry is mixed by agitation in the tank. Sample collection is via a valve in a recirculation loop fitted with a collection valve. Each slurry batch is sampled and analyzed for composition and then transferred into the CFMT, MFHT, or other process vessel via the tank diverter valve. The system is configured for maximum flexibility in slurry transfer.

The three slurry tanks are constructed of 304L stainless steel and are vertical cone-bottomed and equipped with integral cooling jackets. The tanks are designed and fabricated in accordance with the methods and practices of the ASME Boiler/Pressure Vessel Code Section VIII, Division I, and have been "U" stamped.

The system has a maximum single batch slurry working volume of 18.93 m^3 (5,000 gal), and is designed to handle up to a 60 weight percent total solids slurry without plugging. Transfer of cold chemical feed slurry to the Vitrification Cell is accomplished in a single transfer operation, which is followed by demineralized water and utility air line flushes to the CFMT. The flush water is carefully metered and minimized to decrease the amount of time required to boil-down the slurry in the CFMT. The utility air line used for flushing the line is equipped with a restricting orifice to ensure that the CFMT ventilation is not overwhelmed, thereby pressurizing the tank.

Transfer of cold chemical materials into and out of mix tanks is designed for complete movement (i.e., essentially zero tank heel and residual material). The transfer rate of cold chemicals to the Vitrification Cell is designed to maintain sufficient fluid velocity to preclude line plugging caused by solids settling in the line. Maximum cold chemical feed particle size during transfer to the Vitrification Cell is typically maintained at around 50 microns (1.97E-03 in) and utilizes an in-line size-reduction unit, i.e., a grinder. Each slurry tank is equipped with a grinder. The grinder may be used in both recirculation and transfer modes. At the end of each transfer, metered flush water is used to completely clean the slurry tank and recirculation and transfer piping.

All transfers of chemicals from the Cold Chemical system tanks to the Vitrification Cell are governed by formal procedures. For all transfers to the cell, notification and coordination with the VF Control Room are made prior to initiating the transfer to set the required conditions for the transfer and to monitor the status of the transfer. A permissive, initiated by the VF Control Room operator, is required from the VF Control Room DCS to enable slurry transfer diverter valves for Cold Chemical system tanks (65-D-02, -03, -04) to be placed in the "transfer" position. Continuous communications are maintained with the VF Control Room while transferring slurry to the Vitrification Cell to allow securing the transfer if any anomalies are experienced in the process operations.

C.6.5.1.2 Nitric Acid and Caustic Soda Day Tanks

Nitric acid and caustic soda are brought onto the site by tank truck and fed into their respective day tanks, 65-D-05 and 63-D-06. Overfill protection for each tank is provided by means of a high-level alarm and shutoff of the feed valve if the level indicator reaches the preset level for the tank. Both tanks are vented via the Cold Chemical Building Vessel Vent system and are maintained at a nominal negative pressure of -51 mm (-2 in) WC, primarily to prevent outleakage of vapors. Transfer out of the day tanks is controlled via a metering pump. Accurate volumetric transfer of the acid or caustic solution is measured and controlled via a flow meter coupled with a flow totalizer. Table C.6.5.1.2-1 shows the possible transfer destinations for each day tank.

Both the nitric acid and caustic soda day tank Transfer systems have interlocks that prevent:

- transfer of the day tank solution to more than one tank at a time;
- transfer of solution into a full tank;
- simultaneous transfer of acid and caustic soda;
- dead-heading the transfer pump.

C.6.5.1.3 Decontamination Solution Make-up and Transfer

Three cold chemical tanks (65-D-07, 65-D-08, and 65-D-09) are used to prepare decontamination solutions for the vitrification process. The decontamination solutions projected to be used are demineralized water, dilute nitric acid, dilute sodium hydroxide, mild detergent solution, dilute oxalic acid, dilute potassium permanganate, and dilute potassium dichromate.

Decontamination Tank 65-D-07 is used to store and transfer demineralized water for various uses. For reasons of operational safety, the following capabilities have been disabled (lock and tag) from the vessel: nitric acid fill, caustic soda fill, liquid eductor fill, cooling water supply and return, steam supply and condensate return, and agitator motor. The density instrument has been removed. These functions can be reinstalled if the need arises.

Decontamination tank 65-D-08 is used for preparation and transfer of dilute nitric acid for the Nitric Acid Hold Tank (63-D-048). As with Tank 65-D-07, for reasons of operational safety, the condensate return, and liquid eductor fill capabilities have been removed from the vessel. The caustic soda fill, steam supply, air supply to the steam control valve, and density instrument have been removed. These functions can be reinstalled if the need arises. In addition, Tank 65-D-08 has been "hard piped" to 63-D-048 via the transfer pump 65-G-08.

Demineralized water (for flush or fill) can be metered into Tanks 65-D-07, 65-D-08, or 65-D-09. Nitric acid and sodium hydroxide can be separately metered into the tanks from day tanks 65-D-05 and 65-D-06, respectively. Miscellaneous liquid chemicals can be weighed and transferred into the tanks via a steam jet Transfer system.

After preparation, the decontamination solution is sampled and then transferred via a pump and flexible transfer hoses to one of the following locations:

- Vessel Vent Condenser (63-E-015)
- Vessel Mist Eliminator (63-C-032)
- HEME #1 (63-T-033)
- HEME #2 (63-T-036)
- CFMT Demister (63-V-001)
- CFMT Decontamination Fill (63-V-001)
- Vessel Vent Header Flush
- SBS Scrubber Vessel (63-V-031)
- SBS Receiver Vessel (63-V-031)
- MFHT Decontamination Fill (63-V-011)
- Waste Header North Branch Flush
- Waste Header East Branch Flush
- Transfer Tunnel Spray Nozzles
- CMR Decontamination Area Hose Connection
- EDR Decontamination Area Hose Connection
- Nitric Acid Hold Tank Connection (63-D-048)

- Drain Tank Fill (65-D-01)

- Analytical Lab (sampling).

Under normal operations, transfers of dilute nitric acid from decontamination tank 65-D-08 to the Nitric Acid Hold Tank (63-D-048) are made via pump 65-G-08. The other two decontamination tanks (65-D-07 and 65-D-09) may be serviced by transfer pumps 65-G-07 and 65-G-08. The transfer pumps are flushed with demineralized water, after usage for other than the normal solution, to prevent unwanted chemical reactions within the pump and piping. The system is designed for maximum flexibility, so that the two decontamination pumps 65-G-07 and -08 may be used to transfer material from any of the three (3) decontamination tanks 65-D-07, 08, 09, if required.

Tank 65-D-08 is "hard-piped" to Tank 63-D-048 via its dedicated pump. This decontamination storage tank is located just outside the cell wall near the decontamination station at the 37.8-m (124-ft) elevation. The dilute HNO_3 is used for glass canister decontamination, which uses $Ce^{+4}(NO_3)_3$ solution. The Ce^{+4} is added to the nitric acid in the discharge pipe of Tank 63-D-048 during gravity transfer of the tank volume to the in-cell decontamination vessel. This decontamination step is immediately followed by a second batch of dilute nitric acid for flushing the canister. Therefore, two batches of dilute nitric acid may be prepared approximately every 65 hours.

For all transfers, notification of and coordination with the VF Control Room is made prior to initiating the transfer to set the required conditions for and to monitor the status of the transfer.

C.6.5.1.4 Drain Tank

Tank 65-D-01 is used as a hold tank for truck disposal of rinse and waste solutions, and non-recoverable off-specification batches from the slurry mix tanks and other tanks in the Cold Chemical Building. The tank (capacity 41.6 m^3 [11,000 gal]) can hold up to two batches from the 18.9 m^3 (5,000-gal) slurry mix and hold tanks.

Solutions sent to Tank 65-D-01 for truck disposal are evaluated prior to pick-up to determine if they are subject to Resource Conservation and Recovery Act (RCRA) regulations as hazardous wastes (as defined in 40 CFR 261) and subject to treatment and disposal requirements of 40 CFR 268. The hazardous waste determination is made based upon process knowledge, if well documented, quantified data is available concerning the contents of the tank. If sufficient process knowledge is not available to determine the hazardous characteristics of the solution, representative samples are taken and analyzed to make the hazardous waste determination.

The most likely parameters which would make it a RCRA hazardous waste are corrosivity (pH less than or equal to 2 or greater than or equal to 12.5) or toxicity due the presence of heavy metals such as chromium used in decontamination solutions such as potassium dichromate. If the solution is determined to be RCRA hazardous, the commercial firm used to pick-up the waste is required to be an Environmental Protection Agency (EPA) permitted treatment/storage/disposal facility and the truck load will be manifested as a hazardous waste shipment as required in 40 CFR 262. Otherwise it is disposed of as an industrial waste.

C.6.5.1.5 Pneumatic Subsystem for Solids Transfer

The Vac-U-Max pneumatic Transfer system is employed for the transfer of ingredient powders into the slurry mix tanks (65-D-02, 65-D-03, and 65-D-04). Powdered (dry) chemicals needed for decontamination tank use are mixed in 65-D-04 to take advantage of the Vac-U-Max. Drums containing slurry ingredient powders are staged in the drum handling and weigh-out bay on the west end of the Cold Chemical Building. This area is known as the Cold Chemical Scale Room (CCSR). The drums are placed on weigh scales and their contents transferred into the slurry mix tanks per recipe requirements using the Transfer system. A record is kept of the mass of all materials transferred, as required in the governing written operating procedure. The estimated conveying rate to the tanks is 1,361 to 2,722 kg/hr (3,000 to 6,000 lb/hr).

The pneumatic Transfer system consists of a common blower (65-H-01) to provide the motive vacuum to three transfer subsystems (one for each tank). Each transfer subsystem consists of a pick-up wand, transfer tubing, and a receiving hopper from which the powder is fed directly into the slurry tank by means of a dump and isolation valve. The system is operated from the Vac-U-Max control panel, also located in the drum CCSR. The subsystems can only be operated sequentially, so that slurry preparation occurs in one tank at a time.

C.6.5.1.6 Steam Jet Subsystem for Liquids Transfer

The steam jet subsystem is employed for transfer of ingredient liquid chemicals to the slurry tanks (65-D-02, 65-D-03, and 65-D-04) and decontamination tanks (65-D-07, 65-D-08, and 65-D-09) from containers such as drums. The configuration consists of two subsystems, one for the slurry tanks, and the other for the decontamination tanks. The two subsystems are not operated simultaneously.

Each subsystem consists of a liquid eductor and associated pick-up wand connected to a 689 kPa (100 psi) saturated steam supply for motive force, air supply for line flush, and piping to the serviced tanks. The decontamination system is capable of conveying at a rate of approximately 106 L/min (28 gpm). The slurry system has a conveying rate of approximately 18.9 L/min (5 gpm).

The steam jet subsystem is located in the CCSR. Drums containing the liquid ingredient chemicals are staged here, placed on weigh scales, and their contents transferred to the chosen receiving tank per recipe requirements using the liquid eductor material pick-up wand.

C.6.5.1.7 Vessel Ventilation Subsystem

All tanks are vented to the Cold Chemical Building Vessel Ventilation subsystem, which maintains a negative pressure of up to -254 mm (-10 in) WC in the tanks. The Vessel Ventilation subsystem consists of two venturi scrubbers in series with associated scrub solution tank and pumps to provide the motive force for creation of the vacuum. The total solids and pH of the scrub solution are monitored on a periodic basis, and maintained within operating range by bleed off and addition of fresh demineralized water.

C.6.5.2 Equipment Decontamination Room

The EDR, formerly used to support reprocessing activities, is used to receive empty canisters and canister lids, as well as other equipment such as replacement jumpers and filters, and handling fixtures from the Load-In Building. Using the EDR crane, the above equipment is placed on the canister transfer cart for delivery through the Transfer Tunnel to the Vitrification Cell.

The EDR has two 9.07-MT (10-ton) hoist trolleys and three confinement and shielding doors. These doors connect to the HLWIS, the Transfer Tunnel leading to the Vitrification Cell, and to the Load-In Building, which is used to bring in new equipment.

C.6.5.3 High-Level Waste Interim Storage

The HLWIS is located in the former Chemical Process Cell (CPC). It has been converted to perform the following functions for the waste vitrification activities:

- Off-loading the canister transfer cart using the cell crane with grapple attachment and placing them in the storage rack.

- Storage of failed equipment which has been removed from service in the Vitrification Cell.

- Size reduction activities to process used (expended) components to fit within available drums and boxes.

- Storage of glass shard archive samples taken from the canister prior to welding the canister lid in place.

- Removal of decay heat from the stored canisters by means of the HVAC system.

All of these activities are performed remotely by operators utilizing the cell shielded viewing windows and CCTV cameras. The Main Plant/Head End Ventilation system provide HEPA filtered supply and discharge HVAC services to the HLWIS that are monitored and operated by the Main Plant operators.

Primary HLWIS equipment includes storage racks for the product waste canisters, racks for storing archived glass shards from each canister, the cell crane and handling fixtures, shielded viewing windows, CCTV cameras, canister transfer cart, chop saw, the HLWIS/EDR shielding door, and the HVAC system components. Equipment removed from service in the Vitrification Cell is also stored in the HLWIS until it can be size reduced, as needed, and removed.

The Head End Ventilation System, which services the HLWIS, is expected to provide the primary means to remove decay heat from the stored waste canisters. Two fan cooler modules are located inside of the HLWIS in case the Head End Ventilation system cannot keep up with the heat load. A fan cooler would be made operational if the HLWIS air temperature near the ceiling reaches approximately 38°C (100°F).

Each fan cooler system consists of a fan/motor module (15-hp, 460 v, 3 phase) and a heat exchanger unit. The fan forces air through the heat exchanger which is cooled by air cooled chilled water units located outside the Main Plant. These units are dedicated to support the HLWIS fan cooler modules. The cooler modules are designed for remote maintenance and replacement. The modules can be positioned, connected, and maintained using the cell crane and a remotely operated impact wrench. Electrical and chilled water connections to the cooler modules are made by means of special jumper connectors designed for remote operations.

C.6.6 Control Systems

C.6.6.1 Process Instrumentation and Controls

The data collection and control system for the vitrification process is a computerized system called the Distributed Control System (DCS). The DCS allows monitoring, control and supervision of vitrification processes from the VF Control Room, and monitoring of vitrification processing in the process engineering and system engineering office areas. The four DCS work stations in the VF Control Room are redundant with each other (i.e., each can be used to implement the full set of functions available to the vitrification operators). Control of process and support equipment can also be performed from four local cabinets located in the Operating Corridors around the Vitrification Cell and from one cabinet in the instrument room in the 01-14 Building. The DCS architecture is shown on Figure C.6.6.1-1.

The DCS provides data collection and/or control functions for the following structures, systems, and activities:

- Cold Chemical Building
- In-Cell Off-Gas System
- Ex-Cell Off-Gas System
- Ammonia Supply/Injection System
- Continuous NO_x Analyzers
- HVAC
- Sludge Mobilization System
- Closed-Loop Cooling Water System
- Steam System
- Utility Air and Instrument Air System
- Utility Water System
- Turntable
- Waste Header System
- Vessel Vent System
- Primary Vitrification Process
- Canister Decontamination
- Electrical Backup Systems (UPS, diesel generator).

DCS data displays and control functions are provided through computer-driven cathode ray tube (CRT) systems that provide process information and status in graphical process flow diagram form to facilitate interpretation and operations. The data displays include key operating parameters such as vessel levels, temperatures, valve positions, pressures, flows, etc., in real time.

Manual process operation is also possible in the event of loss of computer function. Operable backup components are designed to assume control of failed components for control and monitoring functions.

Key process inputs to the DCS are audibly and visually alarmed to highlight changes from a normal process set point condition or to designate the timing for the next process operation. Select primary process alarm and interlock information is provided in Table C.6.6.1-1. Numerous other alarms and interlocks exist. Restricted access (key-operated or of similar design) is provided for certain functions such as functional control changes, alarm setting changes, and interlocking set point changes, where required.

Electronic permissives are present coordinating the operations of the melter airlift and the canister turntable. The airlift cannot be started if the turntable is moving. Conversely, the turntable cannot be operated if the airlift has air flow going to it. Shut off of the airlift during canister filling operations is done manually by the vitrification operator due to the relatively slow filling rate of the canisters. Audible alarms, shown in Table C.6.6.1-1 are present to key the operator that the canister is full.

Interlocks are provided to control many key processes. The DCS is designed such that various plant processes are interlocked and require certain permissives prior to implementation. Processes such as material transfers are interlocked to prevent overfilling of receiving vessels. The interlocks are also listed in Table C.6.6.1-1.

For control loops in the automatic mode, operations are performed according to programmed operating parameters without operator assistance. A variety of visual displays inform operators of process parameters. CRT displays include process variables, set points, alarm points, and other required operating information. Audible alarms are provided where needed. Control loops have a manual mode that allows the VF Control Room operator to directly control field devices through the DCS. In addition, field devices may be operated from the Operating Corridor, outside of the Control Room after putting the controller into local mode. In the event that the Vitrification Building is evacuated, special coding is available to enable the stations in the process and system engineering office areas to be used for control, in addition to monitoring.

DCS power is fed from an uninterruptible power supply (UPS). The UPS is a self-contained battery-driven alternate power source with a diesel generator back-up. The UPS is designed to float on the line and automatically pick up the load if loss of normal off-site power occurs.

C.6.6.2 DCS Architecture

The DCS components include twenty-four Micon controllers, three sets of PLCs, and three printers. Communication capability is provided to the site's Digital Equipment Corporation computer for analytical and actuarial purposes.

Data from process instrumentation is fed to the DCS cabinets through an intermediate termination cabinet near the DCS cabinets using coaxial cable, twisted pair cable, and instrument cable. Data received by the DCS cabinets from process instrumentation is fed to the DCS through a general purpose local area network (LAN) interface (GPLI) module and into an ethernet network.

DCS Cabinets 1, 2, and 3 each contain a backup controller that can take over the functions of a failed controller instantaneously. DCS Cabinet 4 contains a backup U32 controller that takes over instantaneously from a failed primary U32. Each of the controllers in the DCS also has a backup. Each of the communication interface modules between the operator work station and the controllers have a backup.

PLCs that interface with the DCS are provided for the Vitrification Building HVAC system (panel 67-V-019), the 01-14 Building (panel 64-B-002) and the SMS (panel 55-B-12). Panels 67-V-019, 64-B-002 and 55-B-12 have back-up (redundant) processors.

C.6.6.3 Detection System and Locations

Radiological and environmental conditions were taken into consideration in the design of process instrumentation. To the extent possible, process sensors, electronic components, and other detection devices are located outside high radiation areas so that they can be readily maintained. Process sensors or other components located in the in-cell area can be remotely replaced with the use of remotely controlled tools and cranes. All sensors are located on jumpers which are fitted with standard connectors for remote handling. The bolts holding the jumpers in place are loosened, one-by-one, using the remotely controlled impact wrench which is mounted on the crane hook. The wrench is positioned by using the crane motions described in Section C.6.4.2.

Provisions are included to allow for performance of diagnostic tests on equipment, provide malfunction alarms, and identify locations and types of malfunctions. Process instrumentation is designed to allow for easy maintenance, calibration, and testing during operation, without process interruption. Process loop redundancy is maintained through the use of multiple sensors in important applications.

Where practical, process signal cabling and wiring used to transfer signal energy from the in-cell processes are terminated in low-radiation or clean areas with the use of jumpers.

Process control devices are not located in harsh environments that could adversely affect their accuracy or create excessive maintenance problems. Instrument air to the process and control components is supplied from the Instrumentation Air system.

C.6.6.4 Instrumentation and Control Power Supply System

Power supply systems for instruments and control, including UPS and standby generator power, are described in Section C.5.4.2.

C.6.6.5 System and Component Redundancy and Back-up

The Process Control system is designed to ensure the automatic transfer to a controlled, safe standby condition at particular set points as well as the capability to accomplish a controlled, safe shutdown in the event of equipment failure. To accomplish this, operable backup components are designed to take over in the event of a component failure, key inputs are redundant, UPS are used to ensure power availability, and devices are configured to fail in a safe mode.

The system is capable of functioning as a set of independent controllers if Control Room operation is interrupted. Control of the processes can be maintained by directly operating the controllers locally. Interlocks for equipment and environment protection are provided.

Routine maintenance that has an impact on continuous operation processes is minimized by redundant instrumentation that allows processes to continue while maintenance or equipment change out is conducted.

C.6.6.6 VF Control Room

Radiological protective clothing and equipment are available, readily accessible, and properly stored in a radiologically clean area. Normal operation of the vitrification chemical process is monitored and supervised from the Control Room located within the Vitrification Building at elevation 34.9 m (114.6 ft). The VF Control Room arrangement is shown in Figure C.6.6.6-1.

The Control Room equipment provides:

- Centralized monitoring, alarm and data recording functions for the vitrification process, including feed transfer and make-up, glass formulation, off-gas treatment and filtering, and auxiliary systems required by the vitrification and off-gas processes (e.g., Cooling Water system).

- Interlocks (via permissives) with various local control panels for processes that do not require centralized control (e.g., sludge mobilization, cold chemical transfer to the Vitrification Cell).

- Status indication, alarm and data recording functions related to the Radiation Monitoring system, Fire Detection and Protection systems, HVAC systems, and the ILDS.

Vitrification systems that provide information to the DCS are listed in Section C.6.6.1. As shown in Figure C.6.6.1-1, data signals are sent to the VF Control Room CRTs from the following process area control panels:

- Vitrification DCS Cabinets 1, 2, and 4

- Ex-Cell Off-Gas Instrument Room DCS Cabinet 3 and Control Panel

- HV Operating Station Control Panel

- SMS Control Room Control Panel.

Many of the mechanical support systems, including the canister weld station, turntable, transfer cart, decontamination station, crane, and grapple are controlled from control stations located in the cell Operating Corridors. These operations are observed, but are not controlled, from the VF Control Room. In some cases, such as operation of the turntable and solution transfers from the Cold Chemical Building to the Vitrification Cell, equipment operation can only be done at the local control station after obtaining a permissive control signal from the Control Room.

The basic control, monitoring, and alarm functions in the VF Control Room are provided by the following equipment:

- Two operator work stations, enabling Control Room operators to monitor and supervise all operations in the VF that are interconnected with the DCS.

- One shift engineer work station, serving as back-up for operator work stations, a process engineering work station, and a work station for configuring/programming inputs.

- One monitoring station (in the shift supervisor office), enabling the shift supervisor to monitor all operations in the VF interconnected with the DCS.

- Fire control panel, providing power and annunciation, supervision, and control capabilities for the fire detection and alarm capabilities.

- Control Room radiation monitoring rack, for polling the radiation monitor communication network that gathers readings and alarm status for display, annunciation, alarm acknowledgement, and data storage.

- Glass Pour Viewing system, providing Control Room operators with a means to view and record glass pour operation.

- CCTV distribution cabinet, providing interface between Control Room CCTV stations and field CCTV stations and cameras.

- ILDS, providing a method of monitoring the level of molten glass in the canisters.

The DCS is an automated system that allows the vitrification process to be performed to programmed operating functions and parameters. Various displays such as process variables, set points, alarm points, levels, and other operating information inform the operators of process parameter status. Alarms are annunciated in the Control Room, on the operators' screens and on the alarm printers, if parameters go beyond operating limits. Unexpected status inputs produce alarms on the screens and printers. Status alarms are wired in a fail-safe mode, to the extent possible; that is, a closed circuit is required to consider an input in its normal state.

Three sets of PLCs and 24 DCS controllers are provided. If control cannot be accomplished from the VF Control Room for any reason, (e.g., communication failure, failure of all four work stations, fire, etc.), many control and monitoring functions can be maintained from non-VF Control Room locations. The PLCs can be operated from local CRT based operator interfaces, and the DCS controllers from front-of-panel devices. In the event that the Vitrification Building must be evacuated, the monitoring stations in the process and system engineering office areas can be configured for control of vitrification processes.

The CCTV system includes seven stations within the Operating Corridors at which a portable monitor could be plugged in for viewing. The Glass Pouring system also allows monitors to be plugged into local control boxes. The ILDS has a local monitor at its control station in the operating aisle (with reduced graphics capability). The Radiation Monitoring system includes local alarms at each monitoring station, in addition to the alarms annunciated in the VF Control Room. These consist of both flashing lights and audible alarms. In case access is unavailable to the Control Room, the Fire Protection system would still sound warning horns in the aisles and in the guard house. Water extinguishing components are triggered locally, rather than from the Control Room.

The VF Control Room is designed with human factors in mind such that:

- All controls, displays, and alarms needed for detection of abnormal conditions and putting the VF into a safe condition are available to the operators at the immediate operator work station.

- Placement and spacing of equipment allows operators full view of the CRT display panels and unimpeded reach for all controls at the immediate operator work station.

- Work station placement facilitates voice communications between operators seated at the work stations.

- Operator maneuvering space complies with NUREG-0700, Section C.6.1.1.3.

- All equipment dimensions meet the requirements of NUREG-0700, Section C.6.1.2.

- All office furnishing, landscape partitions and components comply with NFPA 101, *Life Safety Code® Handbook*, Chapter 31.

- The shift supervisor's office is located to allow prompt physical access to the operator work stations under all conditions and to permit good visual and voice contact with the operator work stations.

- Rest rooms and cafeteria facilities are located near the VF Control Room to allow personnel access to these facilities without delay, as recommended by NUREG-0700 and EPRI NP-2411, *Human Engineering Guide for Enhancing Nuclear Control Rooms*.

- Emergency exits are provided for evacuation of the VF Control Room.

Procedures and drawings that may be needed for references are kept in the VF Control Room and stored where they are easy to locate and use.

Radiological protective clothing and equipment are available, readily accessible, and properly stored in a radiologically clean area near the VF Control Room. Procedures and instructions for donning and using personal protective equipment are located within the VF Control Room.

Emergency equipment, including portable fire extinguishers and required radiation and rescue equipment is available to the operators in the VF Control Room area. Fire Protection systems and extinguishers (types and locations) are in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

To ensure that visual effectiveness is sufficient for task performance, the level of illumination in the general areas of the VF Control Room is 75 foot-candles dimmable to 25 foot-candles. Individual dimmers allow lighting levels to be adjusted in the areas of the work stations. Local lighting at reading and writing locations is designed for 100 foot-candles. Lighting fixtures have diffusers and lenses constructed of nonflammable materials.

The Emergency Lighting system is automatically activated and available upon failure of the normal Control Room Lighting system. The power source is independent of any Lighting system that is available in the VF Control Room. The source of power for the emergency lighting is battery packs. These are designed to provide one-half hour of lighting for safe shutdown of select components and evacuation of the VF Control Room. As noted in Section C.6.6.5, the processes can be controlled from the various local DCS independent controllers, if desirable. To ensure reliability and operability, battery packs are tested monthly.

The VF Control Room Emergency Lighting system is designed to provide a minimum illumination level of 10 foot-candles at all work stations.

Restricted access to the VF Control Room is provided by card readers. Access to changes to the DCS software configuration, such as alarm limits, are restricted by the use of passwords and controlled mechanical keys used in controllers. The "configuration/programming mode" is only entered at the DCS master's work station and is controlled by procedures.

Communication from the VF Control Room is by four identical master desktop paging and communication units plus one field intercom station. Master desktop communication units are equipped with "All Page" and have ten talk lines and ten special lines for listening and communicating. The master desktop communication units are located at the shift supervisor's station, shift engineer's station, and each of the operators' stations. The field intercom station is located on the side of the layout table.

C.6.6.7 Cold Chemical Instrumentation and Controls

The Vac-U-Max pneumatic Transfer system for feed powders has its own control panel. Level elements are employed to monitor liquid level in the Cold Chemical Building tanks. Slurry tanks (65-D-02, 03, 04) and the Drain Tank (65-D-01) utilize bubbler type probes, while the other process tanks (65-D-05, 06, 07, 08, 09) utilize capacitance probes. There is an agitator trip at low liquid level in all tanks equipped with an agitator. This prevents the agitator from turning when blades are not adequately submerged, protecting the shaft from uneven thrust.

All tanks are equipped with a high-level alarm. In addition, all slurry and decontamination tanks have a trip at high level to prevent addition of caustic soda (from Tank 65-D-06) or nitric acid (from Tank 65-D-05) to a full tank. The caustic and nitric tanks (65-D-06, 05) have an automatic trip on the supply line at high level to prevent overfilling the tanks.

Control panel 65-CP-01 houses the system alarms and switches for turning on equipment and valves. Control panel 65-CP-02 is used to activate automatic valves in the various transfer lines to the Vitrification Cell.

The Vac-U-Max control panel is used to select the tank to which powdered ingredient chemicals will be transferred into and to switch on the vacuum blower 65-H-01. In addition, lights on the panel indicate the operational sequence unit as it occurs.

The cold chemical equipment is operated from the control panels described above. The system is run in an unsupervised and unmanned mode during certain periods of time (i.e., while awaiting results of sample analysis). Should an alarm condition develop at the Cold Chemical control panel 65-CP-01, it is relayed to the VF Control Room via a common Cold Chemical system alarm. This alarm sounds in the VF Control Room if the local Cold Chemical Building alarm is left unacknowledged for a preset period of time.

C.6.6.8 Cell Viewing and Lighting Systems

Six CCTV units are located in the Vitrification Cell to aid in viewing. The vitrification process crane also has five video cameras mounted on it. In addition, one CCTV camera is located in the Transfer Tunnel, two are mounted on the EDR bridge crane, one is mounted on the CCR platform, one is on the HLWIS wall, and one is mounted on the 14.51-MT (16-ton) trolley/hoist in HLWIS. Each crane control station has pan and tilt and telephoto zoom capabilities controlled from the work stations to allow the maximum viewing of cell and processing operations.

The Vitrification Cell has six oil-filled lead glass viewing windows for shielded viewing of remote operations. The CMR also has an oil-filled lead glass viewing window to observe the cranes as they are being moved into the CMR and to monitor contact maintenance operations in the CMR. The HLWIS has four original oil-filled lead glass viewing windows. The CCR and the EDR had zinc bromide windows that have been converted to oil-filled windows to provide observation of contact maintenance operations in these rooms.

The Vitrification Cell is illuminated with thirty-two high-pressure sodium (HPS) 400-watt bulbs with ballasts located in the Operating Corridor. These light fixtures are remotely replaceable using the process crane. The process crane also has six HPS lights with ballasts built into the fixtures. The cell lighting was designed to assure 50-foot candles effective lighting at all work stations. Due to the significant transmission loss of light through lead glass shielding in the shield windows, actual in-cell lighting levels are over 200-foot candles to assure an effective 50-foot candles through the windows. The CCTV system operates effectively at significantly lower light levels, but is not adversely affected by the higher light levels being provided. The Transfer Tunnel is illuminated with six HPS 100-watt fixtures which is sufficient for CCTV transmission. There is no direct (shield window) viewing into the Transfer Tunnel.

The HLWIS crane lighting has HPS fixtures identical to the process crane fixtures. The HLWIS lighting was originally fourteen remotely changeable 1,000-watt mercury bulbs with ballasts outside the HLWIS. Seven of these lights have been replaced with new fixtures with 1,000-watt HPS bulbs and new HPS ballasts located outside of HLWIS. Since no remote operations are possible in the HLWIS without the cranes in the cell, most of the lighting is from a single row of eight HPS fixtures on the 14.51-MT (16-ton) bridge crane and six HPS fixtures on the 1.81-MT (2-ton) power manipulator bridge. The in-cell lights are sufficient for CCTV transmission and general viewing without the cranes in HLWIS.

The lead glass in shielded viewing windows is a relatively poor transmission media for purple, blue, and green portions of the spectrum. Even at 589 nanometers (sodium peak from HPS lights), transmission is only approximately 40%. Color rendition through lead glass windows is thus not particularly good. In addition, the selection of HPS lighting does not allow good color rendition. Thus, little dependence has been placed on color coding within the Vitrification Cell. Where identification is needed, or status, location, or position determinations are required, high-contrast markings are used rather than color.

C.6.7 Sampling and Monitoring Systems

Process control of VF operations is accomplished by a combination of on-line and off-line analyses. As much as possible, on-line monitoring instrumentation is used for the continuous monitoring of process streams.

The primary process streams and parameters which are monitored on-line are discussed in Section C.6.6.1 and shown in Table C.6.6.1-1. Where continuous monitoring of a desired parameter is not feasible, grab samples are taken for off-line analysis in a process control laboratory. The VF includes provisions for the following:

- On-line and off-line analyses to provide operating personnel with information required to control processes in accordance with process parameter guidelines (defined in operating procedures) such as CFMT acceptable range requirements given in Table C.6.2.2-1 and final vitrified glass product requirements shown in Table C.6.2.4-1.

- Historical data required to evaluate the efficiency of the process and optimize process performance.

- Verification of the composition of essential materials and batch make-up of cold chemical solution sent to the Vitrification Cell.

- Verification of the feed slurry composition in the CFMT and MFHT tanks, prior to transfer to the SFCM.

- Verification of the composition of process effluents prior to discharge to the environment to ensure that limits are not exceeded.

The only VF process effluents which are discharged to the environment are released from the Main Plant stack after treatment and filtering in the Process Off-Gas system. Ex-cell off-gas effluents that are monitored include NO_x, NH_3, alpha activity, and beta/gamma activity.

C.6.7.1 Process Sampling

C.6.7.1.1 CFMT and MFHT Slurry Sampling

Sampling capabilities of process vessels are provided by the Slurry Sample System (SSS). The SSS is an integral part of feed preparation and its purpose is to collect samples of the slurry from the CFMT and MFHT. These samples are then transferred to the Analytical Lab for analysis. The SSS is located beneath the north-west shielding view window of the Vitrification Cell (see Figure C.6.1.2-1).

The SSS is composed of two major components, the sample station and air displacement slurry (ADS) pumps. The sample station is approximately 1,829 mm long by 914 mm deep (6 ft long by 3 ft deep) and is mounted on the wall at the Sample Transfer Station near the northwest cell window. The station consists of two sampler modules and interconnecting pipes and valves. Each sampler module consists of a sampler mechanism, flow meter, and flow control valves. One module is used to sample the CFMT and the other is used to sample the MFHT. Two identical ADS pumps are used to circulate slurry from the CFMT and MFHT to each sample module and back again. The vessel samples are taken from this circulated stream from each vessel.

Prior to collecting samples, the SSS is put into pump mode to circulate slurry through the sample station and back to the tank. The system is circulated for a period of time to ensure that the circulating slurry is representative of the tank being sampled. After the required circulation time is completed, the samples are taken.

The sampler handle is operated by the manipulator to fill the 10-ml (0.34 oz) sample bottle (bottles are pre-labeled prior to being transferred into the Vitrification Cell through a transfer drawer). The in-cell remote manipulators are used to place a screw-top lid on the sample bottle. The bottle is cleaned by placing it in an ultrasonic water bath, located at the sampling station. The operator visually checks and logs the sample identification number and then places the bottle in the gravity transfer sleeve using the manipulators. The sleeve leads to the shielded sample transfer cell (STC), located on the "cold" side of the Vitrification Cell north wall. The bottle passes through the transfer sleeve into a rabbit in a holding fixture within the STC. The rabbit cap is put in place with the STC remote manipulators.

To initiate a sample transfer, the rabbit containing a sample is placed in the STC sending unit by an operator using remote manipulators. The operator initiates the sample transfer by operating a switch which signals the analytical laboratory that a sample transfer is requested. After acknowledgement, the analytical laboratory operator activates the transfer from the control panel located at the analytical laboratory receiving station. Approximately one minute after the transfer switch is activated, the rabbit arrives in the receiver inside the laboratory hot cell receiving station.

The rabbit is tracked during transfer by means of installed passage photocell detectors that energize panel-mounted signal lights as the rabbit passes the detectors. If the rabbit is not received into the laboratory hot cell, detectors in the transfer line trip and automatically shut the suction system down and close the inlet and outlet suction line valves. Indicator lights on the control panel reveal the relative position of the rabbit in the transfer line. The reverse transfer switch is then activated to reverse the suction direction, open the inlet and outlet valves, dislodge the rabbit, and return it to the sending unit.

The Vitrification Sample Transfer system is a modification to the Supernatant Treatment system pneumatic Sample Transfer system. The modifications include:

- An STC designed to place sample bottles in the transfer rabbits, cap the rabbits and place them into the pneumatic Transfer system using remote manipulators. The STC consists of a fabricated assembly of a 4.8-mm (0.188-in) thick stainless steel liner with 76-mm (3-in) thick carbon steel shielding and supporting structural framing. The STC is designed in accordance with shielding requirements anticipated for processing laboratory samples from the Vitrification Cell.

- A pneumatic sending unit atop the STC.

- New transfer tubing from the sending unit to the tie-in with the existing Sample Transfer Station to the process building pneumatic transfer line.

- A diverter valve at the junction to select the transfer path.
- Equipment installed in the Vitrification Building to provide for a reverse transfer.
- Associated control devices with applicable instrumentation to monitor and control system operations.

Transfer tubing, couplings, pneumatic equipment, control devices, and monitoring instrumentation are identical to those items for the existing system.

The STC utilizes the following utilities:

- Electrical power: 120-volt single-phase 60-Hertz for lighting and manipulators.
- Water: wash water for decontamination, as required.

The Sample Transfer system is designed to meet the following criteria:

- The STC, the reverse transfer equipment, the sending unit, and portions of the transfer tubing are to operate under indoor temperature conditions. The diverter valve and transfer tubing installed on the roof of the Vitrification Building are insulated and heat-traced to operate under outdoor ambient temperature conditions at WVDP.
- Sample transfers are accomplished under negative pressure or vacuum conditions.
- Inlet and discharge air for the transfer line passes through HEPA filters to prevent contamination escape.
- Radiation shielding surrounding the STC and administrative controls in place maintain exposure levels ALARA.
- The system maintains a vacuum in the transfer line from the process building for normal sample transfers and from the Vitrification Building for reverse transfers.
- The inside surface of the STC, transfer tubing, and fittings are made of stainless steel, sample bottles are made of glass, and the "rabbit" is made of polyethylene.

- Transfer line components, installed outside the buildings, are insulated and heat traced to maintain a temperature within the line above the ambient dew point temperature to prevent condensate formation on the inside of the tube and valve surfaces.

C.6.7.1.2 Glass Product Sampling

Samples of glass product in the canisters must be analyzed to confirm that the glass meets specifications. This is done by collecting small fragments from the top of the glass in the filled canisters. As the glass cools, it cracks, leaving small shards atop the bulk of the glass in the canister. These are ideal for sampling. Only 0.5 grams (1.1E-03 lb) is required for a sample for analytical purposes.

Glass samples are taken as dictated by process procedures and/or run plans for the following functions:

- Process control samples (typically from every tenth canister)
- Random samples as required by the Waste Qualification Report (WQR) (typically 10% of canisters, chosen at random)
- Archival samples for qualification data for glass per the WQR (taken from each canister and retained for future reference).

The archival samples are not analyzed immediately but are placed in containers for future storage in the HLWIS for future analysis, if necessary.

The shard samples are taken at the canister weld station using the remote manipulator at that location. A specially designed air-driven ejector is placed in the canister fill neck to "vacuum" some of the tiny glass shards. These shards are emptied into a specially designed funnel apparatus which directs the shards into a pre-labeled sample bottle.

After the sample is obtained, it is transferred across the cell by the cell crane to the SSS. At this station, the samples are handled and sent to the analytical laboratory using the same handling procedures and equipment used for the slurry samples. Archive samples, which are not sent to the laboratory, are accumulated in a storage container for later transfer by the transfer cart into the HLWIS for storage.

C.6.7.2 Gas Sampling and Monitoring

On-line monitoring of off-gas is done to assure that the NO_x treatment and particulate filtering units are operating properly. As shown in Table C.6.6.1-1, the

Off-Gas system is monitored continuously for various gas parameters including treatment component temperatures and liquid levels. Monitored gas parameters, which are indicators that the gas released from the stack is properly treated and filtered prior to release, include:

- Off-gas temperature which is measured prior to HEPA filtration to ensure that moisture does not condense on the filter media, which could damage the filter.

- NO_x concentrations entering the converter and subsequent to the converter but prior to stack release. This measurement ensures that the converter is operating properly.

- NH_3 released to the stack which was not destroyed in the NO_x converter.

- Alpha and beta/gamma activity in gases released from the stack, which is continually measured by stack monitors. The stack monitors are fed by an isokinetic probe located in the exhaust stack to ensure that a representative gas sample stream is taken. This measurement ensures that particulate filtration components are functioning properly.

C.6.7.3 Process Sample Analyses

Samples transferred from the STC to the analytical facilities on the third level of the former reprocessing facility are received in the shielded sample storage cell, from which they are sent to one of five shielded analytical cells.

These five analytical cells are identical, each being about 2 m x 2 m x 2 m (6.6 ft x 6.6 ft x 6.6 ft) in size, and have the equivalent of 1.5 m (5 ft) of concrete shielding and remote manipulator capabilities.

The samples are opened and handled in the analytical cells. Some sample analysis is done in the analytical cells, and the samples are split and diluted. Following dilution, the samples are pneumatically transferred to the vitrification laboratory, located in an adjacent room, for routine hands-on chemical analysis.

The samples are analyzed as required for chemical species important to glass formulation stability. Specific analyses are conducted as required for the following parameters:

- Density;

- Solids content;

- Fissile material concentration;

- Level of radioactivity;
- pH;
- Specific chemical species, as required.

Liquid wastes resulting from analytical activities are routed to the Main Plant Liquid Waste Cell Tank 7D-14. (See other DOE-approved WVDP safety documentation.) This bulk tank is transferred to Tank 7D-2. A portion of Tank 7D-2 is transferred to Tank 3D-2 where it is sampled and analyzed. The contents of Tank 3D-2 are transferred back to Tank 7D-2 after the sampling is complete. The waste, in Tank 7D-2, is then evaluated and conditioned (i.e., pH adjusted), if necessary, for compatibility with its disposition point which is Tank 8D-2.

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Table C.6-1

Vitrification Process Steps

Locations (see Figure C.6-2)	Process Description
1,2,3,4	HLW slurry is pumped from the waste tank farm to the VF Concentrator Feed Make-up Tank (CFMT) through a double-walled transfer line pipe located in the HLW transfer trench.
5,6,7,8,11,12,22	CFMT Mix Step - The HLW is partially nitrated with nitric acid recycled from the SBS and mixed with glass formers and additional cold chemicals, as required, from the CCS. CFMT Reaction Step - The mixed chemicals are stirred (agitated) and allowed to react. Conditioned slurry is transferred, by steam jet ADS pump, to the MFHT, which meters the feed to the SFCM at a continuous rate.
9	CFMT Concentration - Water is evaporated from the slurry until the proper liquid content is reached in the HLW slurry.
10	Overheads from the evaporation process (condenser) are routed to Tank 8D-3 for treatment by the LWTS.
13	SFCM Conversion Step - Melter feed is transferred into the SFCM where the mixture is heated to make the feed mixture molten.
14	SFCM Separation Step - The molten glass product is poured into a stainless steel canister and the off-gas routed to the off-gas system.
15	The canister is filled, cooled, and transferred to a canister welding station where a closure lid is welded to close the canister fill opening.
16,17,18,19	SBS Mix Step - Off-gas from the SFCM is routed to the SBS where it is quenched to below 45°C. The off-gas enters the bottom of a flooded packed bed and bubbles up through it.
20	SBS Reaction Step - Vapor-liquid contact is provided to remove the larger particulates.
21,22,23	SBS Separation Step - Scrubber solution containing particulates is recycled to the CFMT where it is mixed with other wastes and glass formers. Off-gas from the SBS is routed to the HEME.
24	The HEME collects and coalesces entrained liquid droplets and removes submicron particulates from the gas. It is 99.8% (w/w) efficient for liquid droplets 3 microns in diameter and larger.
24,25	The HEME fiberglass is cleaned with a water spray to control pressure drop. Wash water will be recycled back to the SBS and periodically transferred to the CFMT.
26	The scrubbed off-gas is heated in the HEPA preheaters before passing through HEPA filters and is then routed through a line in the off-gas trench to Building 01-14 for final HEPA filtering, NO_x removal, iodine removal, monitoring, and main plant stack release.

Table C.6.2.1-1

Typical Glass Forming Chemicals*

Compound
Al_2O_3
B_2O_3
$C_{12}H_{22}O_{11}$
Fe_2O_3
$Fe(OH)_3$
H_3BO_3
KOH
$LiOH\ H_2O$
$Mg(OH)_2$
MnO_2
$Na_2B_4O_7\ 10H_2O$
Na_3PO_4
NaOH
SiO_2
TiO_2
ZrO_2

* Data taken from Vitrification Process Development, October 10, 1989.

Table C.6.2.2-1

Typical Target and Acceptance Range for CFMT Feed Elements and Primary Constituents of the Finished Glass Composition

Species	Target (wt%)	Minimum (wt%)	Maximum (wt%)
Al_2O_3	6.00	5.43	6.57
B_2O_3	12.89	10.96	14.82
CaO	0.48	0.36	0.55
Fe_2O_3	12.02	10.22	13.82
K_2O	5.00	4.38	5.63
Li_2O	3.71	3.25	4.17
MgO	0.89	0.76	1.02
MnO	0.82	0.70	0.94
Na_2O	8.00	7.00	9.00
P_2O_5	1.20	1.02	1.38
SiO_2	40.98	38.76	43.19
ThO_2	3.56	3.03	4.09
TiO_2	0.80	0.68	0.92
UO_3	0.63	0.47	0.72
ZrO_2	1.32	1.12	1.52
Other	1.70	0	11.86

Table C.6.2.3-1

Process Off-Gas Stack Radionuclide Release Data

Isotope	Maximum Release[1] (Ci/yr)	Maximum Specific Activity[1,2,3] (μCi/cc)
H-3	3.6	1.3E-7
C-14	1.7	6.1E-8
Sr-90/Y-90	9.0E-5	3.2E-12
I-129	4.3E-1	<1.5E-8
I-131	7.3E-5	2.6E-12
Cs-137/Ba-137m	2.3E-3	8.3E-11
Rn-220	3.5E+3	1.3E-4
Pu-238/239/240	4.4E-9	1.6E-16
Pu-241	3.8E-8	1.4E-15
Am-241/243	3.2E-5	1.2E-12

Except for I-131 and Rn-220, source of table is Roberts, April 2, 1990. I-131 and Rn-220 information is taken from Dames & Moore, September 30, 1996.

1. Based on start-up conditions slurry feed rate to the melter of 150 L/hr, except for I-131 and Rn-220.
2. Based on a volumetric off-gas flow of 1868 ACFM, except for I-131 and Rn-220.
3. Specific activity for I-131 and Rn-220 may not be maximum values.

Table C.6.2.4-1

Typical Glass Physical Properties

Property	Value
Density (Room Temperature)	2.695 ± 0.007 gm/cm^3 (unannealed) 2.699 ± 0.002 gm/cm^3 (annealed)
Viscosity	Log_{10} h = -2.85 + 4205.5/(T - 458.28) Where: h = viscosity in poises T = temperature in degrees K T (100 poise) = 1,049 ± 5°C
Upper Linear Expansion Coefficient	99.02 x 10^{-6}/°C
Lower Linear Expansion Coefficient	10.76 x 10^{-6}/°C
Dilatometric Glass Transition Temperature (T_G)	469 ± 5°C
DSC Glass Transition Temperature (T_G)	472 ± 3°C
Dilatometric Softening Point (T_D)	506 ± 5°C
Heat Capacity (C_p)	C_p (150°C) = 0.791 C_p (400°C) = 0.825
Heat Conductivity	$0.5 - 1.5 \frac{KCal\text{-}cm}{sec\text{-}cm^2 - {}^\circ C}$ *Temperature Dependent*
Lower Annealing Point (LAP)	453 ± 5°C
Upper Annealing Point (UAP)	484 ± 5°C

Table C.6.3.1-1
Off-Gas System Design Data

Item	Component	Description
1	Vessel Vent Header	Uninsulated, 150 mm (6 in), 304 SS Schedule 40 pipe.
2	Vessel Vent Condenser	304L SS, 3.2 GJ/h (3 X 10^6 BTU/hr) vertical shell and U-tube heat exchanger, 760 mm diam. by 3350 mm high, 343 each 19 mm (3/4 in) 18 BWG tubes.
3	Submerged Bed Scrubber (SBS)	Hastelloy C-22 receiver vessel, 2,400 mm diam. by 3,350 mm tall, 5.5 m^3 working volume. Inside the receive vessel is a Hastelloy C-22 scrubber vessel with 2.27 m^3 capacity, Inconel 690 downcomer, 150 mm (6 in) in diam., bed of 10 mm diam. ceramic spherical packing.
4	Mist Eliminator	304L SS housing; knitted 304 SS wire mesh pad, 360 mm diam. & 150 mm thick. Pad is designed for 200 mm/s upward face velocity for particle capture by impaction.
5	HEME Preheater	304L SS housing; 50 Kw, 480 Volt, 3 phase, electrical resistance immersion style element sheathed in Incoloy 800.
6	High Efficiency Mist Eliminator (HEME)	304L SS housing, 1,070 mm diam. by 4,060 mm tall, with wound fiberglass mesh pad 76 mm thick, 610 mm inside diam., & 3,050 mm tall. The pad is designed for 1,500 mm/min to 12 m/min horizontal face velocity for particle capture by Brownian motion.
7	Filter Preheater	304L SS housing with 50 kW, 480 Volt, 3 phase, electrical resistance immersion style element sheathed in Incoloy 800.
8	Prefilter Assemblies	304L SS housing with two HEPA elements in series.
9	Postheater	304L SS housing with 50 kW, 480 Volt, 3 phase, electrical resistance immersion style element sheathed in Incoloy 800 .
10	Duct to 01-14 Building	Insulated 250 mm (10 in) 304 SS; Schedule 40 pipe
11	Entrainment Separator	250 mm (10 in) 304L SS Schedule 40 pipe housing slanted baffles for droplet capture by impaction.
12	Reheater	304L SS housing with 60 kW, 480 Volt, 3 phase, electrical resistance immersion style element sheathed in Incoloy 800.
13	HEPA Filters	304L SS housing holding two parallel filter trains each having two HEPA elements in series.
14	Blowers	Rotary lobe, positive displacement blowers; adjustable frequency drives designed to provide a maximum flowrate of 42.5 m^3/min (1500 ACFM), and normally operated at a speed to motivate about 27 m^3/min (950 ACFM); 75 hp, 460 Volt, 3 phase

Table C.6.3.1-1 (Concluded)
Off-Gas System Design Data

Item	Component	Description
15	Preheaters	Insulated 304L SS housings holding two 101 kW, 480 Volt, 3 phase, electrical resistance immersion style elements sheathed in Incoloy 800.
16	NO_x Catalytic Converter	Insulated 321 SS vessel 4,300 mm tall and 1,000 mm diam., housing a catalyst bed, downflow design, 890 mm of zeolite based catalyst in the form of 6 mm Raschig rings, plus 230 mm of zeolite based catalyst in the form of 1.6 mm extrudate.
17	Ammonia Storage Tank	Carbon steel tank 5,200 mm tall and 1,070 mm in diam. having a 3.8 m^3 capacity.
18	Ammonia Vaporizers	304L SS housings with 18 kW, 480 Volt, 3 phase, electrical resistance immersion style elements sheathed in Incoloy 800.
19	Off-Gas Discharge Duct	Insulated, 200 mm (8 in) SS pipe

Table C.6.4.2-1

Crane Motion Speeds

Crane	Bridge Travel Rates [fast/slow] (ft/min)	Trolley Travel Rates [fast/slow] (ft/min)	Hoist Lift Rates [fast/slow] (ft/min)	Hoist Rotation Rates [fast/slow] (revolutions/min)
Cell Process	12/4	12/4	15/5	1.5/0.5
Cell Back-up	12/4	12/4	6/2	N/A
HLWIS	9.5/3.2	9/3	6/2	N/A
EDR	12/4	9/3	6/2	N/A

Table C.6.5.1-1
Cold Chemical Building Tanks Operating Parameters

Tank	Tank Description and Use	Tank Construction	Features	Normal Tank Pressure	Normal Operating Temp.	Cooling Capacity (BTU/Hr)
65-D-03 Main Mix Tank	Tank for preparation of feed slurries for the CFMT and MFHT (5,000 gal nominal operating capacity).	304L SS, "U" stamp, Vertical cone bottomed tank with integral cooling jacket.	Level, pressure, temperature instrumentation; 15 Hp tank agitator, low-level automatic agitator trip; High-level alarm; high-level trip of nitric/caustic addition.	0 to -10 in H_2O	Room temp. - 140°F	200,000
65-D-04 Shim Tank	Tank for addition of shim chemicals to the CFMT and MFHT (500 gal nominal operating capacity).	304L SS, "U" stamp, Vertical cone bottomed tank with integral cooling jacket.	Level, pressure, temperature instrumentation; 2 HP Tank Agitator; Low-level automatic agitator trip; High-level alarm; high-level trip of nitric/caustic addition.	0 to -10 in H_2O	Room temp. - 140°F	170,000
65-D-02 Holding Tank	Hold tank for batches produced in 65-D-03 (5,000 gal nominal operating capacity)	304L SS, "U" stamp, Vertical cone bottomed tank with integral cooling jacket.	Level, pressure, temperature instrumentation; 15 Hp Tank Agitator; High-level alarm; high-level trip of nitric/caustic addition.	0 to -10 in H_2O	Room temp. - 140°F	200,000
65-D-05 Nitric Acid Day Tank	Tank used for storage of concentrated nitric acid (nominally 65 wt. %). Operating capacity - nominal 1,500 gal. Max. allowed working volume 1,722 gal.	304L SS, "U" stamp, cylindrical tank with dished heads	Level, pressure, and temperature instrumentation; High-level alarm coupled with shutoff of the acid feed valve; Sample port	0 to -10 in H_2O	Room temp.	N/A
65-D-06 Caustic Day Tank	Tank used for storage of concentrated sodium hydroxide (nominally 50 wt. %). Operating capacity - nominal 500 gal.	304L SS, "U" stamp, cylindrical tank with dished heads	Level, pressure, and temperature instrumentation; High-level alarm coupled with shutoff of the caustic feed valve; Sample port	0 to -10 in H_2O	Room temp.	N/A
65-D-07 Decontamination Tank	Tank for storage and transfer of demineralized water for various VF use. (1,000 gal nominal operating capacity).	304L SS, "U" stamp, cylindrical tank with dished heads and cooling jackets	High-level alarm; Sample port; Steam heating available; Agitator (normally locked out)	0 to -10 in H_2O	Room temp. - 190°F	N/A
65-D-08 Decontamination Tank	Tank for preparation and transfer of dilute nitric acid for the decontamination mix tank (63-D-048) and other VF uses. (250 gal nominal operating capacity).	304L SS, "U" stamp, cylindrical tank with dished heads and cooling jackets	High-level alarm; High-level trip of nitric addition; Sample port; Cooling available; Agitator; Low-level agitator trip.	0 to -10 in H_2O	Room temp. - 190°F	N/A
65-D-09 Decontamination Tank	Tank for preparation and transfer of miscellaneous decontamination solutions for various VF use. (250 gal nominal operating capacity).	304L SS, "U" stamp, cylindrical tank with dished heads and cooling jackets	High-level alarm; High-level trip of nitric addition; Sample port, cooling and steam heating are available; Agitator; Low-level agitator trip.	0 to -10 in H_2O	Room temp. - 190°F	N/A
65-D-01 Drain Tank	Tank for temporary holding of off-spec. slurry mix batches. (11,000 gal nominal operating capacity).	304L SS, cylindrical tank with dished bottom and flat top.	High-level alarm; sample port	0 to -10 in H_2O	Room temp.	N/A

Table C.6.5.1.2-1

Possible Day Tank Transfer Destinations

Nitric Acid Day Tank 65-D-05	Caustic Soda Day Tank 63-D-06
Decontamination Tank 65-D-07	Decontamination Tank 65-D-07
Decontamination Tank 65-D-08	
Decontamination Tank 65-D-09	Decontamination Tank 65-D-09
Shim Mix Tank 65-D-04	Shim Mix Tank 65-D-04
Drain Tank 65-D-01	Drain Tank 65-D-01
Holding Tank 65-D-02	Holding Tank 65-D-02
Main Mix Tank 65-D-03	Main Mix Tank 65-D-03

Table C.6.6.1-1
Vitrification Process Alarms and Interlocks

System	Parameter	Alarm	Interlocks
CFMT	Level	Hi-Hi	No additions permitted to tank
	Level	Low	Agitator operation is prevented/stopped; steam to jacket is prevented
	Pressure	Hi-Hi	Steam to jacket is prevented/stopped
	Bottom & Side Coil Pressure	Low	Air flow to coils is initiated
	Bottom & Side Coil Steam Flow Rate	High	None
	Demister Pressure Drop	High	None
	Agitator Current	High & Low	High current deactivates agitator
MFHT	Level	High	No additions permitted to tank
	Level	Low	Agitator operation is prevented/stopped
	Pressure	High	None
	Agitator Current	High & Low	High current deactivates agitator
SFCM	Level	Hi-Hi	Melter feed pump operation is prevented/stopped
	Level	Low	None
	Pressure	High	Melter feed pump operation is prevented/stopped, film cooler air flow and air injection air flow is prevented/stopped, and valve to vessel vent header is opened.
	Pressure	Low	None
	Temperature	High	None
	Temperature	Low	None
	Electrode Penetrations Cooling Air Flow	Low	None

Table C.6.6.1-1 (Continued)
Vitrification Process Alarms and Interlocks

System	Parameter	Alarm	Interlocks
SFCM	Electrode Penetration Shrouds Cooling Air Flow	Low	None
Turntable	Canister Fill Weight	High	None
	Rotation	---	Turntable rotation is prevented or stopped if airlift is in progress
Off-Gas and Vessel Vent	Condenser Outlet Temp.	High	None
	Condenser Condensate Level	High	None
	SBS Bed Temp.	High & Low	None
	SBS Scrubber Level	Lo-Lo	Stop feed
	SBS Receiver Level	High	None
	SBS Receiver Level	Lo-Lo	Stop pump
	HEME Preheater Temp.	Hi-Hi	Stop power and feed
	HEME Preheater Off-gas Temperature	Hi-Hi & Low	Hi-Hi - Stop feed, stop electrical power Low - None
	Vent Header Pressure	High	Steam to CFMT prevented/stopped
	Mist Eliminator Diff. Pressure	High	None
	HEME Diff. Pressure	High	None
	HEME Liquid Level	High	None
Off-Gas and Vessel Vent	Prefilter Diff. Pressure	High & Low	None
Ex-Cell Off-Gas	Reheater Off-gas Temperature	High & Low	None
	Reheater Element Temp.	High	Stop electrical power; stop feed
	Blower Suction Pressure	High	Switch blowers
Ex-Cell Off-Gas	Preheater Off-gas Exit Temp.	High & Low	Stop NH_3
	Preheater Element Temp.	High	Stop electrical power; stop feed

Table C.6.6.1-1 (Concluded)
Vitrification Process Alarms and Interlocks

System	Parameter	Alarm	Interlocks
	Converter Exit Temp.	Hi-Hi	Stop feed and NH_3
	Converter Exit Temp.	Lo-Lo	Stop NH_3
	NH_3 Vaporizer Exit Pressure	Low	Switch vaporizer
	Vaporizer Element Temp.	High	Switch vaporizer
	Stack Discharge Off-gas Temp.	Lo-Lo	Stop feed
	NO_x to Converters	High	Stop feed
	NO_x to Stack	High	None
	NH_3 Slip to Stack	High	None
	Stack Alpha Activity	High	None
	Stack Beta/Gamma Activity	High	None
Waste Header	Sumps (North, South A, & B) Level	High	None
Canister Decontamination	Nitric Acid Hold Tank (63-D-048)	High	None
	Decontamination Tank Level	High	Close fill valve (HV-4403) from the nitric acid hold tank
	Neutralization Tank Level	High	None

PROCESS STREAM #	1A	1B	1C	1D	1	2A	2B	2C
PROCESS DESCRIPTION	WASHED PUREX SLUDGE IN 8D2	ADJUSTED THOREX WASTE FROM 8D4 TO 8D2	CAUSTIC ADDITION TO 8D2	WASTE TRANSFER FROM 8D1 TO 8D2	VITRIFICATION SYSTEM FEED FROM 8D2 TO CFMT	SBS RECYCLE TO CFMT	DECON RECYCLE TO SBS	HEME FLUSH RECYCLE TO SBS
WATER, KG	4.63E+05	3.41E+04	2.11E+04	8.48E+05	1.37E+06	1.27E+05	2.52E+05	8.99E+03
SOLIDS, KG	1.16E+05	5.11E+04	2.11E+04	6.45E+04	2.52E+05	4.36E+03	1.19E+04	7.10E+01
VOLUME, L	4.91E+05	5.13E+04	2.77E+04	8.87E+05	1.46E+06	1.27E+05	2.52E+05	8.99E+03
ACTIVITY, Ci	1.14E+07	1.49E+06		1.13E+07	2.41E+07	2.87E+05	1.22E+01	2.01E+03
HEAT GENERATED, W	3.98E+04	4.36E+03		2.80E+04	7.22E+04	Negligible	3.03E-02	Negligible
GASES, KG								

PROCESS STREAM #	2D	2E	2	3	4A	4B	4C	4D
PROCESS DESCRIPTION	OVERHEADS FROM CFMT	GLASS FORMERS ADDED TO CFMT	VITRIFICATION FEED FROM CFMT TO MFHT	VITRIFICATION FEED FROM MFHT TO MELTER	AIR INLEAKAGE TO MELTER	OFF GAS FROM MELTER	AIR TO FILM COOLER	PRESSURE CONTROL AIR TO JUMPER
WATER, KG	1.34E+06	4.05E+05	8.89E+05	1.01E+06	5.01E+04	1.16E+06	1.16E+05	1.79E+05
SOLIDS, KG	3.10E+03	6.58E+05	8.75E+05	8.75E+05		3.27E+03		
VOLUME, L	1.34E+06	7.43E+05	1.23E+06	1.35E+06	3.65E+09	1.28E+10	4.97E+09	7.68E+09
ACTIVITY, Ci	2.83E+05		2.44E+07	2.44E+07		2.89E+05		
HEAT GENERATED, W	8.35E+02		7.22E+04	7.22E+04				
GASES, KG		-1.20E+02			4.18E+06	4.42E+06	5.51E+06	8.52E+06

PROCESS STREAM #	4E	4	5	6A	6	7A	7B	7
PROCESS DESCRIPTION	GLASS PRODUCTION IN MELTER	OFF GAS TO SBS	OFF GAS FROM SBS	OFF GAS FROM VESSEL VENT CONDENSER	CONDENSATE FROM VESSEL VENT CONDENSER	OFF GAS FROM HEME PRE-HEATER	WATER ADDITION TO HEME	OFF GAS FROM HEME
WATER, KG		1.45E+06	1.34E+06	1.18E+05		1.45E+06	8.48E+03	1.45E+06
SOLIDS, KG	5.28E+05	3.27E+03	6.76E+01			6.76E+01		2.26E+00
VOLUME, L	2.20E+05	3.00E+10	2.08E+10	4.07E+09		2.45E+10	8.48E+03	2.47E+10
ACTIVITY, Ci	2.41E+07	2.89E+05	2.16E+03			2.16E+03		1.54E+02
HEAT GENERATED, W	7.22E+04		Negligible			Negligible		Negligible
GASES, KG		1.85E+07	1.85E+07	3.94E+06		2.24E+07		2.24E+07

PROCESS STREAM #	8	9	10	11	12
PROCESS DESCRIPTION	OFF GAS FROM FILTER PREHEATER	OFF GAS FROM FILTER	OFF GAS FROM POSTHEATER	LWTS RECYCLE TO 8D2	DECON RECYCLE TO WASTE HEADER
WATER, KG	1.45E+06	1.45E+06	1.45E+06		
SOLIDS, KG	2.26E+00	2.26E-06	2.26E-06		
VOLUME, L	2.89E+10	2.82E+10	3.07E+10		
ACTIVITY, Ci	1.54E+02	2.59E+00	2.59E+00		
HEAT GENERATED, W	Negligible	Negligible	Negligible		
GASES, KG	2.24E+07	2.24E+07	2.24E+07		

Figure C.6-4
Vitrification Process
Mass Flow Diagram Parameters

C.7.0 WASTE CONFINEMENT AND MANAGEMENT

This chapter addresses the treatment, storage, and disposal of radiological and hazardous materials associated with Vitrification Facility (VF) gaseous, liquid, and solid waste streams.

C.7.1 Waste Management Criteria

Radioactive wastes resulting from vitrification operations include gaseous, solid low-level, liquid high-level, and mixed waste. Nonradioactive, nonhazardous, and nonradioactive hazardous wastes are also generated during processing. The VF has been designed to ensure environmental effluent releases are maintained well within discharge guidelines given in U.S. Department of Energy (DOE) Order 5400.5 *Radiation Protection of the Public and the Environment*, and U.S. Environmental Protection Agency's 40 CFR 261, *Identification and Listing of Hazardous Waste*.

The WVDP integrates the concepts of Waste Minimizations/Pollution Prevention (Wmin/PP) into all of the operations and activities at the Site, continually reassessing the concept throughout the duration of the project focusing upon waste minimization which recognizes true waste costs avoidance. Waste generation managers are required to plan for waste disposal prior to the commencement of work: demonstrating that the waste was preliminarily characterized prior to the commencement of work, preparing an estimate and documentation of the volume of waste to be generated and showing that waste minimization techniques were evaluated to avoid or reduce the volume of waste generated.

The West Valley Demonstration Project (WVDP) has developed comprehensive waste management plans to ensure that radioactive, hazardous, mixed, and industrial wastes are handled and stored in compliance with applicable state and federal regulations. A summary of WVDP waste management plans is given in Table C.7.1-1.

C.7.2 Radiological Wastes

Radioactive wastes from vitrification operations include solid, liquid, and gaseous effluents. Throughout this Final Safety Analysis Report (FSAR), high-level waste feed from Tank 8D-2 is regarded as vitrification process solution, not waste. Byproduct streams resulting from processing which are treated or stored are, however, considered wastes. Throughout this FSAR the term "waste" is not used in a regulatory context.

The WVDP is currently utilizing the U.S. Nuclear Regulatory Commission (NRC) waste classification system prescribed in 10 CFR 61, *Licensing Requirements for Land Disposal of Radioactive Waste*, for Class A, B, and C wastes. Based on this classification system, the primary form of solid radioactive wastes generated during vitrification operations is expected to be Class A waste. This type of waste is generally compactable material consisting of anticontamination clothing, bags, paper products, rags, analytical sample bottles and other miscellaneous items. Other low-level solid wastes include spent ventilation filters, contaminated wood products, small diameter piping, and sheet metal which has been removed from radioactive service and packaged before disposal.

Transuranic (TRU) waste at the WVDP is generated primarily by plant decontamination efforts. At present, there are no major decontamination projects on-site. There are no decontamination projects scheduled as part of vitrification operations, so no significant quantities of TRU waste are expected to be produced during the vitrification campaign. However, some TRU waste may be generated by VF-related sampling activities, equipment maintenance, and expended materials processing.

C.7.3 Nonradiological Wastes

Vitrification process effluents are regulated by the New York State Department of Environmental Conservation (NYSDEC) for nonradiological parameters. Airborne effluents from the ex-cell Off-Gas system are monitored for nitrogen oxides and ammonia to ensure compliance with the discharge requirements of the New York Code of Rules and Regulations (NYCRR). The WVDP has obtained from NYSDEC three Permits to Construct air contamination sources for the Cold Chemical Building. The calculated emissions from these sources during the vitrification campaign are given in Chapter 8.

Liquid effluents are monitored to assure compliance with discharge limits identified in the State Pollutant Discharge Elimination System (SPDES) Permit. These waste streams are also monitored for radioactivity to verify that they are not contaminated by a new source. The Drain Tank (65-D-01) in the Cold Chemical Building is used to collect waste from Tanks 65-D-02 through 65-D-09 resulting from any off-specification mixtures or flushing/draining of lines. Part of the contents of Tank 65-D-01 are transferred as needed into a nonradiological (hazardous or non-hazardous, as appropriate) waste truck for disposal off-site.

A small amount of hazardous waste is generated at the WVDP primarily as a result of maintenance and analytical activities. Handling of these wastes is in accordance with the site *WVDP Hazardous Waste Management Program*, WV-996. There is no on-site disposal of hazardous waste at the WVDP. Hazardous waste is shipped off-site for treatment and disposal by licensed and approved transporters to permitted commercial treatment, storage, and disposal facilities.

A Closed-Loop Cooling Water (CLCW) system is used to provide the necessary cooling for process vessels. The heat transferred to the secondary cooling loop is discharged to the environment via a cooling tower. Wastes associated with handling and processing the chemicals in the Chemical Preparation and Feed system (e.g., empty containers, spilled solutions) is handled in compliance with WVDP-011, *WVDP*

Industrial Hygiene and Safety Manual. Miscellaneous trash (e.g., paper, uncontaminated metallic items) is collected and transported off-site for disposal along with similar wastes generated from other WVDP activities.

Water released from activation of the ammonia tank deluge Fire Suppression system may contain absorbed ammonia (soluble up to 10% by volume). Such a release would follow the normal storm drainage pathways. (See Figure 4-1 of WVDP-043, *West Valley Demonstration Project Oil Hazardous Substances and Hazardous Wastes Spill Prevention Control and Countermeasures Plan*). Contained fire water would seep into the ground and therefore will not reach nearby streams. As required by 40 CFR 117.3, substantial releases of ammonia above acceptable limits would be reported to U.S. Environmental Protection Agency (EPA) authorities. Being a common fertilizer, the absorbed ammonia would not adversely affect the environment.

C.7.4 Gaseous Waste

Gaseous wastes associated with the VF are processed through various types of equipment so that releases to the environment are below all applicable DOE, EPA, and NYSDEC requirements. Chapter 5 of this FSAR provides a substantial discussion on VF Heating, Ventilating, and Air Conditioning (HVAC) systems. Chapter 6 of this FSAR provides a description of the VF Off-Gas system. Chapter 8 of this FSAR develops a source term and dose assessment from HVAC and off-gas emissions. The National Emissions Standards for Hazardous Air Pollutants (NESHAPs) air permit application for the VF HVAC system and VF Off-Gas systems has been transmitted to the DOE West Valley Area Office (OH/WVDP) Director (West Valley Nuclear Services Co., Inc. August 20, 1993 [WD:93:1030]).

The VF has two distinct locations where radioactive airborne emissions are released to the atmosphere. These are the existing main plant stack (for process off-gas emissions) and the stack for Vitrification Building HVAC system emissions. The monitoring program for the existing main plant stack is provided in other DOE-approved WVDP safety documentation.

C.7.4.1 Process Off-Gas

Off-gas from the Slurry-Fed Ceramic Melter (SFCM) passes through a Submerged Bed Scrubber (SBS) and mist eliminator before merging with noncondensible off-gases from the Concentrator Feed Makeup Tank (CFMT), Melter Feed Hold Tank (MFHT), and neutralizing tank. Next, the combined off-gases are directed through various in-cell equipment, namely an off-gas mist eliminator, High-Efficiency Mist Eliminator (HEME), preheater, and pre-filter assembly. The off-gases are then routed to the 01-14 Building where they are processed through a mist eliminator, reheater, High-Efficiency Particulate Air (HEPA) filters, and NO_x removal equipment before being released from the nominal 60-m (197-ft) main stack.

The in-cell portion of the Off-Gas system: 1) Provides safe removal of the process gases from the melter and other vessels while maintaining vessels and ducting at slight vacuum for contamination control; 2) Collects, on in-cell filters, radioactively contaminated particles from the off-gases, thereby aiding in minimizing radiation exposures to operators; and 3) Pretreats off-gases before they leave the Vitrification Cell. The in-cell portion of the Off-Gas system, in conjunction with the Ex-Cell Off-Gas system, is designed to maintain a slight vacuum, 127 mm (5.0 in) water gauge, on process components. The vessel ventilation equipment is to maintain the vacuum regardless of whether 1) Waste is being fed to the melter; 2) The CFMT is contributing steam at a rate of up to 1,043 kg/hr (2,300 lb/hr) to the vent header; or 3) The off-gas jumper from the melter to the Off-Gas system is plugged.

The off-gas treatment equipment is to receive off-gases from the melter when the melter is operated to produce glass at a nominal rate of 30 kg/hr (66 lb/hr). The off-gas equipment is to accommodate off-gases resulting from the high waste feed rate of 150 L/hr (40 gal/hr) associated with melter startup operation. The system is also to receive additional gases and vapors from the vessel ventilation equipment.

To facilitate equipment maintenance without having to suspend melter feed operation, a redundant train of off-gas treatment equipment is installed. Normally, one of the installed redundant off-gas trains is operated while the other off-gas train is valved out of service. While out of service, maintenance operations can be performed.

C.7.4.2 HVAC

Since VF process off-gas emissions are generally of significantly more concern than HVAC systems emissions, and in consideration of the substantial discussion already provided for the VF HVAC systems in Chapter 5 of this FSAR, no further discussion of the HVAC systems is provided.

Systems providing ventilation for the Main Plant building are discussed in other DOE-approved WVDP safety documentation. Filters in these systems ensure a minimum removal efficiency of 99.95% for particulates 0.3 microns (1.2E-05 in) in diameter and larger. Particulate removal efficiency is determined routinely. Air in the Main Plant ventilation system flows at approximately 14.2 m^3/s (30,000 cfm) through a bank of roughing filters and a bank of HEPA filters before exhausting to the stack. Air in the Head End Ventilation system flows at approximately 6.8 m^3/s (14,400 cfm) through a bank of prefilters, a bank of roughing filters, and two banks of HEPA filters in series before exhausting to the stack. Performance of filters in these ventilation systems is monitored continuously through sampling of exhaust air. Redundant spares associated with each of these ventilation systems ensures confinement of radioactivity during abnormal operations. Variation exists in the amount of activity present on ventilation filters removed from service. The quantity of radioactivity depends on the location of the filter in the filter train, the isotopic distribution of radionuclides in the cells ventilated by the ventilation system, and on activities in the plant that generate airborne contamination. Filters removed from service in the Main Plant are handled per approved work procedures and the requirements of WVDP-010. Upon removal, these filters are placed in shielded containers and transferred to lag storage.

C.7.5 Radioactive Liquid Waste

Radioactive liquid wastes associated with the VF are processed through existing systems at the WVDP. Specifically, radioactive liquid wastes are either returned to the Waste Tank Farm (WTF) for subsequent processing though the VF or Integrated Treatment System (IRTS) or processed through the Low-Level Waste Treatment Replacement Facility (LLW2) with subsequent release to the environment. The IRTS is discussed in other DOE-approved WVDP safety documentation. The IRTS reduces activity levels so that the liquid can either be used in the Cement Solidification system (CSS) or sent to the LLW2.

The Waste Header System liquid wastes are high-activity wastes that include solutions such as bad batches from the CFMT or MFHT, scrubber solutions from the SBS, and decontamination solutions from the Canister Decontamination Station and any of the process tank contents that inadvertently are spilled into the floor of the Vitrification Cell and collected in the cell sumps. The only routine flow to the waste header is the intermittent transfer of the rinse water from the Canister Decontamination System. Wastes returned to Tank 8D-4 are eventually recycled back to the vitrification process by pumping the contents of Tank 8D-4 into Tank 8D-2, where it is blended with the contents of that tank as feed to the VF.

Condensates from the vent header contain much less activity than the Waste Header System. This waste consists of condensed steam, produced during operation of the CFMT, and entrained and condensed moisture from the off-gas of the other in-cell process vessels, excluding the SFCM. This waste is returned to Tank 8D-3. The contents of this tank are sampled and analyzed and, based on the analysis and operational need for flushing solutions, are either recycled back to Tank 8D-2 or sent to the Liquid Waste Treatment System (LWTS). Operation of the LWTS is discussed in other DOE-approved WVDP documentation.

Condensate from the moisture entrainment separator in the Ex-Cell Off-Gas system is primarily condensed water resulting from the reduction of the temperature in the Vitrification Cell off-gas, which has been through the cell treatment and filtration equipment. This condensate is accumulated in a condensate tank for subsequent transfer to the south sump of the Vitrification Cell.

C.7.6 Radioactive Solid Wastes

Solid wastes generated during vitrification operations include Class A, B, and C wastes. Temporary storage for these wastes is provided by Lag Storage Facility buildings and hardstand areas; waste volume reduction is performed at the Waste Reduction and Packaging Area compactor, and the Contact Size-Reduction Facility. These facilities have been designed for the safe storage of wastes packaged to meet the requirements of 10 CFR 61. They provide interim storage for wastes generated at the WVDP prior to final disposal off-site; no radioactive wastes produced at the WVDP are disposed of on-site. Solid waste storage and volume reduction facilities are fully described in other DOE-approved WVDP safety documentation. Size reduction of vitrification expended materials (VEM) is accomplished by the Vitrification Expended Materials Processing (VEMP) system, as discussed below.

C.7.6.1 Vitrification Expended Materials Processing System

In 1999, several items were installed in either the Vitrification Cell or High-Level Waste Interim Storage Area (HLWISA) for the purpose of size reducing VEM. These items, coupled with a new electric grabber and existing equipment handling and moving equipment in the VF, constitute the VEMP system. Items used for size reduction of VEM include a plunge saw, guillotine saw, electric hack saw, band saw, electric shear, and a large Adamant™ cutting machine. Each of these items can be remotely operated while within the Vitrification Cell or HLWISA. The transfer cart is used to transfer size reduction equipment and VEM between the Vitrification Cell and HLWISA. The electric grabber is a lifting device that can be attached to either the Vitrification Cell or HLWISA crane. The grabber works by closing two arms onto or around an object and holding the object during movement of a crane. The lifting capacity of the grabber is one ton. Generally, segmented pieces are segregated into one of the following categories:

- Inconel and stainless steel pieces contaminated with glass, but not slurry
- Non-inconel and non-stainless steel pieces contaminated with glass, but not slurry
- Slurry contaminated pieces of any material type
- Airborne contaminated pieces of any material type, with no glass or slurry contamination.

As of March 2000, approximately three to a dozen of each of the following items exist as VEM: thermowells, thermocouples, melter level probes, purex connectors, canister seal flange adapters, pumps (e.g., air displacement slurry and submerged bed scrubber pumps), lids, and "waste cans" (with no listing of their contents). Additional VEM include a conductivity probe, maintenance table test jig, impact wrench, camera stand, camera, gripping tool, port seal, port cover, port shroud, wall plug nozzle, turntable assembly, weld head, guillotine saw, electric shear, measuring jig, brush assembly, melter periscope, two jack stands, two chain vice adapters, and two jaw adapters for a guillotine saw. While not exhaustive, this listing of VEM indicates the types of waste items being generated and managed as VEM. VEM are formally tracked using spreadsheet software. After size reduction as necessary, VEM are placed in drums or boxes, which are subsequently stored in Lag Storage Facility structures or the HLWISA based on the measured dose rate outside the drum or box.

Hazards associated with operation of the VEMP system include falling objects, fire (originating from the frictional heat of operating saws), and mechanical damage to Vitrification Cell or HLWISA structures, systems, or components during size reduction activities. Potentially hazardous scenarios associated with these types of energetic events are considered to be sufficiently addressed in, or otherwise bounded by, the process hazards analysis tables presented in Chapter 9 of this FSAR. Operation of the VEMP system does not present any new or unique accident scenario that is of sufficient risk to warrant detailed (i.e., quantitative) accident analyses.

REFERENCES FOR CHAPTER C.7.0

New York Code of Rules and Regulations. *Identification and Listing of Hazardous Waste*, Title 6 NYCRR, Part 371, as amended.

U.S. Department of Energy. February 8, 1990. Change 2 (January 7, 1993.) DOE Order 5400.5: *Radiation Protection of the Public and the Environment*. Washington, D.C.: U.S. Department of Energy.

U.S. Environmental Protection Agency. *Identification and Listing of Hazardous Waste*, 40 CFR 261, as amended.

__________. *Determination of Reportable Quantities*, 40 CFR 117.3, as amended.

U.S. Nuclear Regulatory Commission. *Licensing Requirements for Land Disposal of Radioactive Waste*, 10 CFR 61, as amended.

West Valley Nuclear Services Company, Inc. August 20, 1993. *NESHAPs Air Permit Application for Vitrification Facility HVAC System*, West Valley Demonstration Project (WD:93:1030). Letter to T.J. Rowland.

__________. WVDP-010: *WVDP Radiological Controls Manual*. (Latest Revision.) West Valley Nuclear Services., Inc.

__________. WVDP-011: *WVDP Industrial Hygiene and Safety Manual*. (Latest Revision.) West Valley Nuclear Services Co., Inc.

__________. WVDP-043: *West Valley Demonstration Project Oil Hazardous Substances and Hazardous Wastes Spill Prevention Control and Countermeasures Plan*. (Latest Revision.) West Valley Nuclear Services Co., Inc.

__________. WVDP-164: *Used Oil Management Plan*. (Latest Revision.) West Valley Nuclear Services Co., Inc.

__________. WV-918: *Waste Minimization Pollution Prevention Awareness Program*. (Latest Revision.) West Valley Nuclear Services Co., Inc.

__________. WV-227: *Planning for Waste Disposals*. (Latest Revision.) West Valley Nuclear Services Co., Inc.

__________. WV-996: *WVDP Hazardous Waste Management Program*. (Latest Revision.) West Valley Nuclear Services Co., Inc.

Table C.7.1-1

Waste Management Plans, Codes and Regulations
Employed at the WVDP

WASTE MANAGEMENT PLAN	LOCAL AND FEDERAL CODES AND REGULATIONS
ENVIRONMENTAL MANAGEMENT AND MINIMIZATION OF WASTES	
WV-980 - WVNS Environmental Management System WVDP-087 - Waste Minimization/Pollution Prevention Awareness Plan	DOE Order 231.1 DOE Order 451.1 DOE Order 5400.1 DOE Order 5400.5 DOE Order 5484.1 DOE-EH-0173T 40 CFR, Various Sections 6 NYCRR, Various Sections
RADIOACTIVE AND MIXED WASTES	
WVDP-019 - Annual Waste Management Plan WVDP-339 - Waste Certification Program Plan WVDP-370 - WVDP Radioactive Waste Acceptance Program WVDP-353 - Waste Management Procedures	DOE Order 435.1 10 CFR 61 40 CFR 264 40 CFR 265 6 NYCRR 373 Federal Facility Compliance Act
HAZARDOUS WASTE	
WV-996 - Hazardous Waste Management Program WVDP-080 - PCB and PCB Contaminated Materials Management Plan	40 CFR 261-268 40 CFR 270 6 NYCRR 370-374 6 NYCRR 376
INDUSTRIAL WASTE	
WVDP-072 - WVDP Asbestos Management Plan WVDP-164 - Used Oil Management Plan	

C.8.0 HAZARDS PROTECTION

This chapter identifies hazards associated with the vitrification process; design features and programs that are in place to ensure that workers and the public are adequately protected from those hazards; an occupational and off-site receptor dose assessment; and a discussion on ensuring that exposures to radiological and hazardous materials are kept as low as reasonably achievable (ALARA).

C.8.1 Assuring that Exposures are ALARA

The Vitrification Facility (VF) has been designed to protect both workers and the general public from the hazards associated with vitrification of the high-level waste (HLW). A formal documented program directed toward maintaining personnel radiation doses ALARA has been established in West Valley Nuclear Services, Inc. (WVNS) Policy and Procedure WV-984, *ALARA Program*. The ALARA Program is based on requirements set forth in 10 CFR 835, the Department of Energy (DOE) *Radiological Control Standard* (DOE-STD-1098-99), and DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. The Radiation Protection Program and the ALARA Program site-specific requirements are outlined in WVDP-010, *WVDP Radiological Controls Manual*, WVDP-076, *Environmental Protection Implementation Plan*, and WVDP-163, WVDP *ALARA Program Manual*. WVDP-131, *Radiological Controls Procedures*, and departmental procedures are used to provide more detailed instructions for workers and technical personnel. A discussion and summary of the ALARA Program is provided in WVNS-SAR-001, *Project Overview and General Information*.

In addition to the Radiation Protection Program, the West Valley Demonstration Project (WVDP) has established a comprehensive Industrial Hygiene and Safety Program for the identification and assessment and monitoring of nonradiological hazards based on the requirements of DOE Order 440.1A. Administration of the Industrial Hygiene and Safety Program is through WVDP-011, *WVDP Industrial Hygiene and Safety Manual*, which incorporates applicable DOE requirements as well as DOE-adopted Occupational Safety and Health Administration (OSHA) standards 29 CFR 1910 and 29 CFR 1926.

A comprehensive Fire Protection Program based on the requirements of DOE Order 420.1, *Facility Safety*, and NFPA-101, *Life Safety Code*, has been developed for the WVDP. Administration of this program is through procedures developed from the WVDP *Fire Protection Manual* (WVDP-177). A discussion of the WVDP Fire Protection Program is provided in WVNS-SAR-001.

C.8.1.1 Policy Considerations

Policy considerations with regard to assuring that occupational hazard exposures are ALARA are provided in WVDP-010 and WVDP-011.

C.8.1.2 Design Considerations

The VF has been designed in accordance with the ALARA principle to reduce radiation doses. Design features that ensure the confinement of radioactivity and radioactive materials to achieve exposure level objectives include the following:

- Vitrification of HLW occurs within a shielded cell.
- Pressure differentials are maintained between confinement zones, and between confinement zones and the outside atmosphere, to ensure that air flow is from areas of lesser potential for contamination to areas of greater potential for contamination.
- Radioactive liquids are transported between tanks via double-walled piping that contains instruments to detect any leakage from the primary piping to the encasement piping.
- Radioactive liquids are processed in sealed vessels that are vented in a controlled manner.
- Ventilation systems ensure that any contaminated air inside a confinement zone is High Efficiency Particulate Air (HEPA) filtered before being discharged to the environment through a stack.
- Liquid spills drain to a sump, from which they are routed for further processing.
- Remote-indicating radiological instrumentation is used to monitor the product as well as cell and process conditions to provide verification that operations are occurring within design limits.
- Filled canisters are moved remotely from the Vitrification Cell to the High-Level Waste Interim Storage (HLWIS).
- Shield walls, shield windows, and administrative controls are used to reduce the radiological dose to operators to less than 500 mrem/yr (5.0 mSv/yr).

Additional mitigative measures provided by design include:

- Use of solid-state electronic instrumentation and control equipment to provide high reliability.

- Use of redundant equipment, sensors and controls in critical aspects of operations.
- Ability to monitor the process via control panel indications.
- Use of Closed Circuit Television (CCTV) to provide a clear and unobstructed view of critical areas.

C.8.1.3 Operational Considerations

The main operational method for maintaining occupational doses ALARA is strict compliance with all requirements of WVDP-010. The *WVDP Radiological Controls Manual* is implemented via a series of radiological control procedures contained in WVDP-131, *Radiological Control Procedures.* In addition, all operations in the Vitrification Cell and HLWIS, including maintenance activities, are performed remotely. To ensure that occupational doses remain ALARA throughout the entire vitrification campaign, shielding requirements for structures, systems, and components (SSCs) (i.e., shield walls, wall penetrations, shield windows) have been set based upon the following criteria:

- The maximum radiation dose rate for a full-time occupancy area shall not exceed 0.25 mrem/hr (2.5E-03 mSv/hr). A full-time occupancy area is one in which an individual may be expected to spend all or most of his or her work day.
- The maximum radiation dose rate for a full-time access area shall not exceed 2.5/t mrem/hr (0.025/t mSv/hr), in which "t" is the maximum average time in hours per day that the area is expected to be occupied by any one individual. A full-time access area is one in which no physical or administrative control of entry exists.
- Higher dose rates than those given above may be allowed if compliance with these two levels would be impractical or prohibitive. Access to areas where dose rates exceed those given above are administratively limited and controlled through postings and radiological work permits.

There are no plans for routine, operational related entrance into the Vitrification Cell, HLWIS, Transfer Tunnel, Equipment Decontamination Room (EDR), and Crane Maintenance Room (CMR) from the commencement of HLW vitrification operations until post-vitrification decontamination. However, personnel may enter the Transfer Tunnel, CMR and EDR for maintenance activities if no HLW canisters are in these areas and the appropriate shield doors are closed.

The only full-time occupancy area is the VF Control Room. Other operating areas are designated full-time access areas. The maximum design occupancy time for these areas is as follows:

VF Areas Maximum Occupancy Times
and Maximum Allowable Dose

Area	Hours/shift	Rate (mrem/hr)
Main Control Room	Full-time occupancy	0.25
Operating Aisles	8	0.31
Work Stations	8	0.31
Regulated Zones	4	0.63
Pipe Chase (elevation 125 to 130 ft)	4	0.63
Roof Area	2	1.25
Crane Repair Room	2	1.25

By limiting exposure rates and occupancy times in this manner, no worker receives an annual dose in excess of 500 mrem (5.0 mSv).

C.8.1.4 Defense-In-Depth

The design of the VF provides defense-in-depth for public and worker safety during normal, off-normal, and accident conditions. Defense-in-depth, as an approach to facility safety, has extensive precedent in nuclear safety philosophy. Defense-in-depth entails the concept that layers of defense are provided against the release of radiological and hazardous materials such that no one layer by itself, no matter how good, is completely relied upon. This philosophy is a fundamental approach to hazard control for nonreactor nuclear facilities, even though nonreactor nuclear facilities generally do not possess the same magnitude of accident potential associated with nuclear power plants.

In keeping with the graded approach concept, no requirement to demonstrate a generic, minimum number of layers of defense-in-depth exists. However, defining defense-in-depth as it exists for a facility such as the VF is important for determining a safety basis. As defined in DOE Order 5480.23 and DOE-STD-3009-94, a safety basis is "the combination of information relating to the control of hazards at a facility (including design, engineering analyses, and administrative controls) upon which DOE depends for its conclusion that activities at the facility can be conducted safely."

The primary layers of defense for the VF are given below in order of relative importance:

- Passive confinement barriers
- Wasteform and limited inventory
- Active confinement barriers
- Alarms and monitors
- Personnel training
- Administrative planning and controls

These features are discussed in Chapters 4, 5, 6, 10, and 11 of this FSAR. Significant aspects of these defense-in-depth features are summarized here to aid the reader in appreciating the large margins of safety incorporated into the VF design and operations.

C.8.1.4.1 Passive Confinement Barriers

The hazard and accident analysis given in Chapter 9 of this FSAR concludes that, during accident conditions, including natural phenomena induced accident conditions, only passive confinement barriers must maintain their integrity to provide an adequate level of confinement of the chemical and radioactive materials being processed. These passive confinement barriers include the Vitrification Cell, CMR, and Transfer Tunnel walls, floors, doors, roofs, shield windows, hatches, and penetrations.

The following passive engineered structures are designed to maintain integrity during Design Basis Earthquake (DBE) and Design Basis Tornado (DBT) accident conditions:

- Vitrification Cell
- Crane Maintenance Room
- Transfer Tunnel
- Transfer Trench
- Secondary Filter Room
- Heating, Ventilation Operating Station (HVOS)
- Diesel Generator Room

The primary passive structures, represented by the first three bullets above, must maintain their structural integrity to ensure that the doses to all on-site and off-site receptors remain below the Evaluation Guidelines provided in Chapter 9 of this FSAR. The VF is designed to maintain the integrity of more SSCs than the minimum required passive structures/features to provide an adequate level of confinement. The intact filter units of the Secondary Filter Room would substantially reduce releases, as passive barriers, and additional active confinement (discussed later) would be introduced when standby power from the Diesel Generator Room is initiated and blowers are automatically restarted (assuming off-site power has been lost).

Releases to the environment can reasonably be expected to be very small, if not negligible, during all accident conditions and especially during natural phenomena induced accident conditions due to the fact that the Secondary Filter Room, HVOS, Diesel Generator Room, and the associated controls and equipment of these rooms are designed to withstand extreme natural phenomena events.

The stainless steel lined process pit and sumps provides corrosion resistance capability to provide long-term confinement of process liquids within the Vitrification Cell.

Liquid HLW slurry being transferred from Tank 8D-2 to the CFMT is contained within the passive barriers provided by the double-walled transfer pipe which is housed by the seismically qualified Transfer Trench. Thus, liquids within the transfer line would have to escape the primary inner transfer pipe, the outer secondary pipe, and the concrete Transfer Trench to escape into the environment. Further, batch transfer of HLW from the Tank Farm to the VF, during steady state operations, is performed only once every 7 to 8 days and the lines are flushed with water after each transfer, eliminating the liquid in the line.

The primary inventories of radioactive liquids and solids that pose a release threat are contained in process vessels located in the Vitrification Cell pit. As discussed in Section C.5.2.6, these vessels will maintain structural integrity and remain stationary during a DBE event. Furthermore, the overhead equipment (e.g., crane, in-cell coolers) will not collapse on the vessels in the pit or the in-cell primary filters of the HVAC system. Thus, it is probable that the process vessels themselves will serve as the containment barrier during and after a seismic event and releases will be negligible during a seismic event.

For the accident scenarios developed in Chapter 9 of this FSAR, the loss of the Process Off-Gas system prefilters (which provide HEPA level filtration) and/or the Ex-Cell Off-Gas line to the 01-14 Building will not result in unacceptable doses to receptors during a DBE accident event. Even though the Off-Gas Trench was not designed to withstand a DBE, it represents a substantial structure and may maintain some or all of its integrity which would aid in reducing releases during an extreme seismic event.

C.8.1.4.2 Wasteform and Limited Inventory

The inventory of liquid HLW within the Vitrification Building is physically limited by the size of the Concentrator Feed Make-up Tank (CFMT) and Melter Feed Hold Tank (MFHT) (which have a combined maximum working volume of 42 m^3 [11,095 gal]). The majority of the radioactive liquid waste inventory is stored in the Tank Farm, away from sources of energy within the Vitrification Cell.

Once the liquid slurry enters the melter, it begins a transition into a much less mobile wasteform. Potential release to the environment is substantially reduced at the point the liquid waste is converted into molten glass. The cooled melter product, which is enclosed in a sealed metal canister, is a relatively immobile vitrified glass wasteform designed to limit release to the environment for tens of thousands of years in a repository environment. Hence, solidified borosilicate glass represents only a small potential hazard to the environment while in interim storage in the HLWIS.

C.8.1.4.3 Active Confinement Barriers

The HVAC system that services the Vitrification Cell (described in Section C.5.4.1.1) creates negative internal pressure (relative to atmospheric pressure) within the Vitrification Cell. Continued operation of the Vitrification Cell HVAC system during and after a DBE event is expected because the HVOS, controls, blowers, filter units, Uninterruptible Power Supply (UPS), and associated stand-by diesel generator are DBE qualified. The system will auto-start on stand-by generator power, upon loss of normal site electrical power. This will eliminate or minimize releases and contamination spread in the operating aisles, associated with the accident. The continued operation of the system suction blowers during an accident event is not essential to maintaining doses to receptors below the Evaluation Guidelines during accident conditions, but is useful in minimizing releases.

The Vitrification Building HVAC and Process Off-Gas systems have parallel (fully redundant) HEPA filter trains (including suction blowers), so more than one train must be damaged before HEPA filtration capability is no longer available. Even though unlikely to occur, damaged or breached HEPA filters offer some particulate removal capability since air passing through the un-breached portion of the filter is filtered. The 01-14 Building off-gas suction blowers are not DBE qualified, but are backed up with stand-by diesel power. Thus, if the system survives the accident conditions, site power is not essential to resume the Process Off-Gas system.

There are three UPSs located in the Vitrification Building that provide power to several important components, instruments, and control systems in the event of loss of off-site power and stand-by power. These components, instruments, and control systems are discussed in Section C.5.4.2.4 of this FSAR.

The Vitrification Cell, EDR, and HLWIS do not have automatic Fire Protection systems installed due to the lack of flammable materials present in them. All other work areas are protected by automatic Fire Protection systems as discussed in Section C.5.4.9. This helps to ensure that fires are detected and controlled before they do significant damage.

A DBE qualified High Pressure Air system is provided to position critical HVAC dampers and valves if loss of the Instrument Air system occurs. The ability to cross-tie utility and instrument air manifolds is also provided to give maximum recovery capability during off-normal plant conditions.

The Closed Loop Cooling Water (CLCW) system provides secondary containment of any radioactive solutions, which might be released in the returned liquids, if the process vessel/CLCW interface is breached. The Steam Condensate Return system from the Vitrification Cell vessels also provides a closed system which would contain a contaminated release from the process vessel. The monitors and alarms for these systems are discussed in the following section.

C.8.1.4.4 Alarms and Monitors

The monitoring and alarm systems for the VF are backed up by UPS, until stand-by power or off-site power can be recovered. If stand-by power or off-site power cannot be recovered, the UPS system provides power to allow for the orderly and planned shut down of the operating systems.

Area Radiation Monitors (ARMs) and Continuous Air Monitors (CAMs) are placed at strategic locations through out the VF to warn operators of elevated radiation and airborne contamination levels. Outputs from these monitors are continually recorded by a dedicated database computer to allow identification of process upsets or changes.

Process systems are continually monitored to determine if leaks are present in the process systems. System leakage is monitored by level monitoring sensors, conductivity probes, radiation monitors, and visual inspection (through cell shielded windows and utilizing closed circuit TV cameras).

Automatic interlocks and operator alarms are associated with various control systems to identify when important process parameters reach levels which require automatic shutdown or operator attention. These controls include Process Off-Gas system alarms and detectors to monitor off-gas released from the Main Plant stack for appropriate levels of NO_x, NH_3, and alpha and beta/gamma radiation. Electronic permissives are required to ensure readiness for substantial transfers of material between physically separated control points such as the Vitrification Building, Tank Farm, Cold Chemical Building, and Analytical Laboratory.

Both the CLCW system and the Steam Condensate Return system have alarmed, in-line radiation monitors to alert operators if the process vessel/heat-exchanger-interface has breached. These systems serve to detect the presence of leaks and prevent radioactive contaminants, that might inadvertently enter the cooling water or steam condensate, from being released to the environment.

C.8.1.4.5 Personnel Training

Qualification standards and training requirements are established for all Vitrification Facility operations positions. Operators are qualified in a accordance with a documented performance-based training program based on requirements contained in DOE Order 5480.20A. This training includes responsibilities and actions during emergency situations. Periodic emergency action drills are performed, with follow-on critiques, to gain experience and confidence and to ensure that plant personnel are ready to respond to accident situations.

C.8.1.4.6 Administrative Planning and Controls

Vitrification operations are accomplished through a clearly defined organizational structure with well defined responsibilities, and operations are conducted in accordance with a protocol that has been established both procedurally and through training. Operational and maintenance activities are controlled through the use of WVNS procedures that implement the applicable DOE Orders.

The *WVDP Industrial Hygiene and Safety Manual* (WVDP-011) establishes the policies used to control chemical and industrial hazards for all West Valley operations. Safety is controlled by use of:

- Proper facility and equipment design.
- Use of proper protective clothing and equipment.
- Training of personnel.
- Safe disposal practices.
- Use of operating procedures.

- Use of Industrial Work Permits.

The *WVDP Radiological Controls Manual* (WVDP-010) establishes the control organization, staffing and training requirements, performance goals, control areas and associated levels, posting and labeling requirements, and other administrative control requirements associated with work in radiation and contamination areas. Radiation field operations use standard industry work control practices including radiation work permits, pre-job briefings, use of personnel protective equipment and clothing, and the wearing of appropriate dosimetry. The principle of maintaining personnel exposures to as-low-as-reasonably-achievable (ALARA) is practiced during all jobs.

Multiple means of communication are established for communications during normal and off-normal plant operations. These include the 812 All-Page System, 222 Plant Page System, Plant Telephone System, Power Fail Telephone System, telecopier, cellular mobile phones, personal pagers, and portable radios.

Periodic walk-downs are procedurally required by both operations personnel and independent organizations. These reviews help to identify developing hazards and process changes.

WVDP uses Process Safety Requirements (PSRs) to reduce worker risk and focus attention on those systems under the direct control of the operator that are important to the safe operation of VF activities. These process requirements define limiting conditions for operation, surveillance requirements, action statements, and the associated bases for systems and/or components under the direct control of the operator that meet the radiological criterion, nonradiological criterion, or the worker risk-reduction criteria defined in WV-365. PSRs are identified in implementing procedures and other documentation. The PSRs are established according to criteria approved by the DOE West Valley Area Office (OH/WVDP). PSRs require the approval of the WVNS Radiation and Safety Committee and select PSRs (based on written criteria) require the additional approval of the OH/WVDP.

C.8.2 Sources of Hazards

There are basically two types of radiological hazards associated with the VF. Radiological hazards are either confined, i.e., within process vessels and piping, or airborne. Shielding is the major protective means for confined hazards, while ventilation is used to control exposures from airborne materials.

C.8.2.1 Confined Sources

The first confined source encountered during vitrification operations is the waste transfer line used to transfer waste from Tank 8D-2 to the Concentrator Feed Make-Up

Tank (CFMT) on approximate 7- to 8-day intervals. The line is flushed after each transfer to eliminate most activity. Calculations show that the 610-mm (2-ft) thick Transfer Trench cover and the 457- to 610-mm (1.5- to 2-ft) thick walls adequately shield the slurry with the highest probable activity concentration to an exposure rate of less than 2.5 mrem/hr (0.025 mSv/hr) at contact on the trench cover (Faillace October 20, 1989). Radiological control technicians' measurements during actual slurry transfers indicate some areas of the Transfer Trench that exceed the calculated exposure rate. Access to the Transfer Trench cover is controlled by radiological posting during slurry transfers.

The confined sources are largely located within the Vitrification Cell. The vessels containing the bulk of activity are:

- CFMT
- Melter Feed Hold Tank (MFHT)
- Slurry Fed Ceramic Melter (SFCM)
- Turntable (containing filled HLW canisters)
- Filled HLW canisters
- Submerged Bed Scrubber (SBS)
- High Efficiency Mist Eliminators (HEMEs)
- HEPA filters.

There are also confined and airborne sources of nonradiological hazards associated with cold chemical slurry preparation for vitrification and the VF Ex-Cell Off-Gas system. The major chemical vessels are listed below:

- Drain Tank (65-D-01)
- Slurry Hold Tank (65-D-02)
- Main Mix Tank (65-D-03)
- Shim Tank (65-D-04)
- Nitric Acid Day Tank (65-D-05)

- Caustic Day Tank (65-D-06)
- Decontamination Tank (65-D-07)
- Decontamination Tank (65-D-08)
- Decontamination Tank (65-D-09)
- Decontamination Mix Tank (63-D-048)
- Anhydrous Ammonia Tank (64-D-004).

Estimated exposures from normal operations releases from these sources are discussed in Section C.8.6.3.

After canisters are filled with HLW glass, they remain within the Vitrification Cell until they have cooled. They are then decontaminated and transferred to the HLWIS for interim storage.

As the waste is vitrified in the SFCM, various radionuclides are expelled into the Off-Gas system at various rates depending upon their chemical form and volatility. Table C.8.2.1-1 presents an activity balance flow sheet for the Vitrification system, including radionuclide-specific decontamination factors (DFs) per the Nuclear Regulatory Commission (NRC), for the In-Cell Off-Gas system.

The majority of the radioactive material is contained in the molten glass placed in canisters. Following cooling in the turntable and the Vitrification Cell, the canisters are moved through the Transfer Tunnel and the EDR to the HLWIS for interim storage. There is a 76-mm (3-in) seismic separation joint between the EDR and new construction associated with the VF. Design aspects of this joint that address possible radiological concerns are provided in Section C.5.2.1.2.

Only a very small portion of radioactive material is expected to leave the Vitrification Cell via the Vitrification Building Heating, Ventilation, and Air Conditioning (HVAC) system. (See Table C.8.2.1-2.)

The most significant points of radionuclide concentration in the Ex-Cell Off-Gas system are expected to be the off-gas HEPA filters and the NO_x abatement system catalyst bed. Design scoping calculations (Vance, October 12, 1994) show that, under worst case assumptions, expected dose rate on the catalyst bed, after one year of operation, will be less than 7 mrem/hr (0.07 mSv/hr) at 610 mm (2 ft).

C.8.2.2 Airborne Radioactive Material Sources

All process vessels, piping, and associated equipment are, in cases of maintenance or process upset, potential sources of airborne radioactivity. To ensure confinement of this airborne radioactivity, all areas having a potential for becoming contaminated are ventilated in a controlled manner. The vitrification process and canister handling activities all take place within ventilation Zone I areas. (Zones are discussed in Section C.5.4.1.1.) These areas are contained within heavily shielded walls and maintained at negative pressures relative to surrounding areas.

Ventilation Zone II areas surround Zone I areas and are maintained at a slightly higher pressure than the Zone I areas to provide proper air flow direction from Zone II areas into Zone I areas. Zone II areas that may be occupied by personnel (e.g., operating aisles) are designed to exclude airborne radioactivity. If activities that take place in these areas could result in airborne contamination, physical controls are implemented via the work document, but if this is not possible, personnel in these areas may be required to wear respiratory protective devices, depending upon the potential for and consequences of any release of radioactive materials to such areas. These areas are continuously monitored for radioactivity and airborne radioactive materials via alarming devices. All continuously occupied areas are ventilation Zone III areas. These areas surround ventilation Zone II areas and are expected to be free of any airborne contamination, but are maintained at a slightly higher pressure than the Zone II areas to ensure air flow from Zone III areas to Zone II areas. Zone III areas are also continuously monitored for radioactivity and airborne radioactive materials via alarming devices. All airborne emissions are continuously sampled isokinetically and continuously monitored for gross radioactivity releases to ensure that releases are within allowable limits and ALARA.

C.8.3 Hazard Protection Design Features

Radiation protective features basic to the design of the VF are dedicated to maintaining radiation exposures to members of the general public and the work force ALARA. Effective control of radiation exposures depends primarily on design features that provide shielding from sources of radiation; remote operations and maintenance; confinement of radioactive materials within the process vessels and piping; proper ventilation; effluent control; and monitoring and surveillance to verify design controls. These physical design features, together with strict adherence to operational requirements presented in WVDP-010, provide effective radiation control.

The automatic Water Deluge system associated with the ammonia tank located near the 01-14 Building is designed to function primarily as a Fire Suppression system. It consists of a 6.1-m (20-ft) high metal frame surrounding the tank. The frame is equipped with sixteen spray nozzles aimed inward and nine heat detectors evenly distributed around the perimeter and height of the tank to provide effective coverage. Since ammonia vapor is partially soluble in water, nine ammonia detectors were added to the grid to activate the Deluge system in the event of an ammonia leak. Both sets of detectors (heat and ammonia) are divided into two groups and cross-zoned; at least one detector from each group must activate to trigger the deluge valve. In accordance with ANSI K61.1-1989, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*, the water spray produces a flow rate of not less than 0.95 L/min (0.25 gpm) per square foot for the vertical sides of the tank and 0.38 L/min (0.10 gpm) per square foot for the top and bottom exposed surface, up to a maximum of 1,893 L/min (500 gpm) (American National Standards Institute, Inc. 1989). The Deluge system is a "dry" system - the flow of water to the outside pipes is valved from inside the 01-14 Building - so freeze protection of the system is not needed. The effectiveness of the Deluge system in mitigating an ammonia release depends primarily upon the location of the failure and the release rate of ammonia.

The Cold Chemical Building HVAC system (as discussed in Section C.5.4.1.5) serves to reduce worker exposure to hazardous chemicals in the Cold Chemical Building during normal and abnormal operations. Based on the results of preliminary cold chemical testing, the expected exposure to airborne dusts and/or fumes to workers in the scale room is well below the threshold values for particulates and chemical vapors. Although Tanks 65-D-01 through 65-D-09 in the equipment area are sealed so they will not release process gas, a Vessel Vent system maintains a negative pressure of 51-mm (2-in) water gauge on each tank. During transfers, when vapors are primarily displaced, the system can draw up to 0.06 m^3/s (133 cfm). Tank vapors are drawn through a venturi scrubber to remove noxious gases, particulates, odors, fumes, and dusts before release to the atmosphere. Therefore, chemical exposures to workers in the equipment area are below particulate and vapor thresholds. Worker monitoring to establish baseline worker exposures is performed, as well as periodic air monitoring.

There are no monitors for nitric acid and caustic vapors in the Cold Chemical Building. Significant leaks into bermed areas activate a sump alarm which notifies the operators and begins pumping the spilled liquid to the Drain Tank, 65-D-01. Detectors for NH_3 and NO_x are installed in the personnel areas in the 01-14 Building as shown in Table C.8.3-1 and the corresponding Figure C.8.3-1.

For nonradiological hazards, the above cited design features and strict adherence to WVDP-011, provide effective nonradiological hazards protection. WVDP-011 addresses the measures required to ensure the safe handling of chemicals and the selection of personal protective equipment required for the handling of hazardous materials and caustic and acid solutions. Additionally, Appendix B of WVDP-011 provides a substantial listing of incompatible chemicals.

C.8.3.1 VF Design Features

To maintain radiation exposures ALARA, the VF design utilizes process isolation and confinement, structural barriers, ventilation, and continuously operating instrumentation that verifies radioactivity confinement. The design includes technology gleaned over the past forty years at commercial and federal installations. Major design features that provide assurance that radiation exposures are kept ALARA are the following:

- The highly radioactive wastes are isolated and processed within a heavily shielded confinement structure that is ventilated in a controlled manner.
- All in-cell maintenance activities are performed remotely.
- The canistered HLW is remotely decontaminated and transferred through the Transfer Tunnel and EDR into the HLWIS for interim storage.
- The occupied areas are continuously monitored for radiation levels and airborne radioactivity levels, and appropriately alarmed to warn workers of abnormal conditions.
- The amount of radioactive and hazardous materials released to the environment is minimized through the use of specialized scrubbers and HEPA filters.

C.8.3.2 Shielding

Shielding is employed with the objective of reducing dose rates to personnel to less than 500 mrem/yr (5.0 mSv/yr). This requirement is met by shielding areas in accordance with the amount of time workers are expected to be in various areas. The maximum allowable dose rates for various locations is given in Section C.8.1.3. Shielding evaluations have been performed for all work areas. The most limiting situation exists for the Vitrification Cell due to the quantity of radioactivity in this cell. The sources of radioactivity in the various vessels in the Vitrification Cell were based on material balance flow sheet data and the general arrangements of these vessels and an assumed maximum inventory within the equipment. Preliminary design calculations of dose rates outside the cell and above the roof were performed using the (VIS) ISOSHLD computer code supplemented by the DOT-3.5 computer code (DiBiase February 20, 1986; March 4, 1986). ISOSHLD is a point kernel gamma ray shielding code. The calculation method used by this computer code involves representing a volume-distributed source of radiation by a number of point sources. The dose from each point source in the source volume is summed to give the total dose. DOT is a two-dimensional discrete-ordinates transport code that solves the Boltzmann transport equation by dividing the physical geometry and gamma-ray energies into discrete components. Additional descriptive information on the computer codes can be found in the user's manuals for the respective codes. The ISOSHLD code was initially used for the walls below 38.7 m (127 ft) and the roof, and the DOT code was used in conjunction with ISOSHLD for the walls above 38.7 m (127 ft) for the preliminary design analysis.

The WVNS Radiation Protection (RP) Department has performed radiation shielding analysis to determine exposure rates in areas adjacent to the Vitrification Cell from the major sources of radiation confined within this cell (O'Ahoofe May 13, 1986). The results of these analyses show that locations below 36.6 m (120 ft) are well below the design criteria of 0.31 mrem/hr (3.1E-03 mSv/hr). (See section C.8.1.3.) The maximum dose rate below 36.6 m (120 ft) is 0.023 mrem/hr (2.3E-04 mSv/hr) at the northeast corner of the Vitrification Building (elevation 32.0 m [105 ft]) in the decontamination and make-up area. The maximum dose rate was estimated to be 3.6 mrem/hr (0.036 mSv/hr) in this vicinity and above the melter power control area along the north wall (elevation 39.6 m [130 ft]). These areas will be controlled administratively by posting and minimizing personnel exposure time as indicated in WVDP-010. The dose rate in the VF Control Room is well below the design limit of 0.25 mrem/hr (2.5E-03 mSv/hr).

Reviews and analyses were also performed regarding shielding design at the Vitrification Cell apron, in the CMR, and for canister lifting scenarios (O'Ahoofe March 24, 1986; April 11, 1986). These analyses indicate that for certain areas (equipment racks external to the recessed portions of the Vitrification Cell walls, the CMR) and during the lifting of canisters for movement within the cell, the appropriate dose rate criteria (0.31 mrem/hr [3.1E-03 mSv/hr] for the CMR, and 1.25 mrem/hr [0.0125 mSv/hr] for the cell roof) may not be met. Additional analyses have been performed (Johnson November 12, 1993) to determine exposure rates at the north and east wall work locations and locations near the HLWIS. The analysis has resulted in an anticipated exposure rate of 0.08 mrem/hr (8.0E-04 mSv/hr) at the north and east wall work locations (windows) for normal operations.

The analysis for the storage of the HLW canisters in the HLWIS was performed (Johnson November 22, 1993) for the wall separating the HLWIS and the off-gas cell and the steel wall separating the HLWIS and the scrap removal room. The analysis was performed assuming that the entire inventory of Cs-137 and Co-60 is stored as HLW in canisters. The original design exposure rate limit for the off-gas cell is 100 mrem/hr (1.0 mSv/hr). This analysis has resulted in an estimated exposure rate of 2.0E-05 mrem/hr (2.0E-07 mSv/hr). The original design exposure rate limit for the scrap removal room is 10 mrem/hr (0.10 mSv/hr). The exposure rate analysis for the scrap removal room resulted in an estimated exposure rate of 7.8E-06 mrem/hr (7.8E-08 mSv/hr).

Due to the size of the Vitrification Cell and number of penetrations, there may be areas that exceed the current design criteria limits. If during the vitrification process an area is found to exceed the design limits, physical controls will be implemented, but if these are not feasible, then access to that area will be administratively controlled (e.g., posting). Throughout the vitrification campaign, routine radiological surveys will be conducted at predetermined survey locations in operating spaces and at the shield wall in accordance with WVDP-010.

Radiation and contamination control for the Transfer Trench and, more generally, the High Level Waste Transfer System (HLWTS), is specified in WVNS-DC-046, *Design Criteria, Sludge Mobilization Waste Removal System*. This document states that "In the controlled access of the tank farm the pits and trench shielding shall be designed to limit the radiation dose rate to less than 2.5 mrem/hr (0.025 mSv/hr) during a waste transfer operation."

Several figures that show the 01-14 Building and a description of the physical attributes of the 01-14 Building are provided in Section C.5.5.4. These physical attributes in conjunction with the very small activity per unit volume of off-gas entering the 01-14 Building as shown in Table C.5.5.4-1, minimize radiological concerns associated with the 01-14 Building.

C.8.3.3 Ventilation

Ventilation systems provided for the VF are designed to ensure compliance with ALARA requirements. All air flow is directed from areas of low contamination potential toward areas of greater potential for contamination. A discussion of the various HVAC systems associated with the VF is provided in Section C.5.4.1 and subsections of that section. The Ventilation system that supports the pump pits is discussed in Section C.5.4.1.8. As shown on Figure C.5.4.1.1-4, there is a pressure relief valve (located within missile grating) in the Vitrification Building HVAC exhaust flowpath. The valve is located immediately prior to the HVAC stack, and relieves at a pressure of 152-mm (6-in) water gauge should the "stack function" not be available.

C.8.3.4 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

The VF is equipped with radiation monitors to warn operators of elevated radiation levels. Gamma radiation fields in all continuously and intermittently occupied areas are continuously monitored by area radiation monitors (ARMs) that have been strategically located. The output from these monitors is continuously transmitted to a dedicated database computer system where they are audited, compared to preestablished radiation background and alarm level values, and stored. Alarm points for detectors located in continuously occupied areas are set by the RP Department. These alarms trigger audiovisual indications in the VF Control Room to alert operators to higher than normal radiation level conditions. The data from these monitors is periodically reviewed to indicate potential trends.

Liquids returning from the Closed Loop Cooling Water (CLCW) system (as discussed in Section C.5.4.6.1) and Steam Condensate Return system (as discussed in Section C.5.4.4) have gamma radiation monitors on return water and steam condensate that are returned from in-cell process vessels. If radiation is detected in these water streams, an alarm sounds both locally and in the VF Control Room.

A network of CAMs is provided throughout continuously and intermittently occupied areas. CAMs located in the VF have preset alarm levels that provide personnel with local audiovisual alarms of elevated airborne concentrations of radioactive material. These alarms also signal in the VF Control Room. All data collected by these monitors is collected and stored on a computer-based data processing system for future reference. Airborne activity trends are analyzed to identify potential problems. Beta CAMs in the 01-14 Building provide local alarms and trending information.

There are also personnel friskers (PFs) at various locations throughout the VF to allow checks of workers for personal contamination. Automated personnel contamination monitors (PCMs) are available to provide a whole body frisk of workers before they exit the building.

For a listing of typical types and locations of various radiation monitoring systems in the Vitrification Building and 01-14 Building, see Table C.8.3.4-1. Also see Figures C.8.3.4-1 through C.8.3.4-6. The specific types and locations of these monitors are determined by the RP Department and may change or be eliminated based on Project needs and/or if determined by the RP Department.

All airborne effluents to the atmosphere are sampled isokinetically and continuously monitored for gross alpha and beta activity. Samples are collected and analyzed for specific radionuclides that are being released to the atmosphere. If preset alarm points are exceeded, audiovisual alarms are activated in the VF Control Room to inform operators of off-normal operating conditions.

There are very low neutron fluences generated by transuranic radionuclides via spontaneous fission and alpha/neutron reactions with low atomic number elements. Nuclear criticality alarms are not required, since a nuclear criticality is not deemed to be a credible accident. (See Section C.9.4.11.)

C.8.4 Occupational Dose Assessment

Occupational doses are maintained ALARA by design and by conducting operations in strict compliance with WVDP-010. As described in Section C.8.1.3, shielding requirements limit occupational doses to less than 500 mrem/yr (5.0 mSv/yr) by limiting dose rates based on projected occupancy times.

The maximum occupational dose for vitrification of HLW is estimated to be about 50 person-rem. This estimate is based on the following assumptions:

- Operation of the VF requires a total of approximately 40 operators.
- Each operator receives an annual dose of 500 mrem (5.0 mSv).
- The vitrification campaign lasts approximately 30 months.

Actual operation of the VF is expected to result in a lower collective occupational dose, since this estimate is based on Project design objective dose commitments.

Internal radiation dose hazards are not expected to be significant, or result in appreciable doses, due to the confinement philosophy and use of airborne activity monitoring equipment. Appropriate respiratory protection devices are required for entry into an airborne radioactivity area if average airborne radioactivity concentrations exceed the Derived Air Concentrations (DAC). Respiratory protection may be required, as determined by the RP Department, when the average airborne radioactivity concentration is less than the DAC depending on the type and characteristics of the work activity to be performed. Per WVDP-179, *Respiratory Protection Program Manual*, respirators are issued only to personnel who are trained, fitted, and medically qualified to wear the specific type of respirator. Training and qualification testing are performed annually.

C.8.5 Hazard Protection Programs

The VF is operated in compliance with the requirements listed in WVDP-010, WVDP-011, and WVDP-177. The Health Physics Program for the VF is the same as for other WVDP activities. The Health Physics Program for the WVDP is described in WVNS-SAR-001, Section A.8.5.

Elements of the Hazardous Material Protection Program ensure that hazardous materials are identified, stored, and handled in a manner consistent with the ALARA philosophy. WV-921, *Hazards Identification and Analysis*, establishes the policy and means "to conduct hazards analyses for all WVNS activities during the work planning process, prior to commencement of work." WV-921 provides "the mechanism for the Work Originator, Work Group Supervisor, and/or Work Review Group to determine when the Hazards Controls Specialists shall be included in the work planning process at a task level." A site Health and Safety Plan (HASP) (WVDP-241) has been prepared to document the WVDP Hazardous Waste Operations and Emergency Response (HAZWOPER) Program, assign responsibilities, establish personnel protection standards, prescribe mandatory health and safety practices and procedures, and provide for contingencies that may arise during the performance of hazardous waste operations work activities at the WVDP. A HASP specific to the vitrification of high-level waste (WVDP-251) also exists. As prescribed by WVDP-011, the site "Right-to-Know" Program (as presented in WV-988) is included in the general employee training required for all employees. Chemical containers received at the WVDP are required to be labelled and accompanied by a Material Safety Data Sheet (MSDS). Handling and storage of hazardous waste is conducted per approved procedures as described in Chapter 7. A detailed discussion of the WVDP Hazardous Material Protection Program is provided in WVNS-SAR-001.

C.8.6 Off-Site Dose Assessment

C.8.6.1 Effluent Monitoring Program

A comprehensive environmental monitoring program is in place at the WVDP to monitor vitrification operations and their possible impact to the environment. Details concerning the overall WVDP effluent monitoring program can be found in Section A.8.6 of WVNS-SAR-001.

Gaseous effluent from the VF is released through two fixed ventilation stacks that are permitted through the Environmental Protection Agency: 1) the existing Main Plant ventilation stack (15F-1); and 2) the VF HVAC system stack (15F-2). The Main Plant ventilation stack monitor and sampler equipment is housed in an insulated building located south of the Main Plant stack base on the Ventilation Exhaust Cell roof. The HVAC stack sampling and monitoring equipment is located in the West Aisle (El. 33.5 m [110 ft]). The pump and flow meter for a seismically-qualified stack sampler is located in the HVOS. The seismically-qualified sample head is located in the missile cage.

At the main plant stack, air is drawn continuously and isokinetically through the sample nozzles and air sample transport line and is first passed through a glass fiber filter, followed by a charcoal cartridge. A fraction of the air from the downstream side of the fiber filter and charcoal cartridge is passed through dessicant columns designed to collect tritiated water vapor (HTO). The main plant stack sample media are changed and analyzed weekly for tritium, gross alpha and gross beta radioactivity. Quarterly composites of the glass fiber filter media are also analyzed for gamma-emitting radionuclides, strontium-90, and actinide radionuclides. Quarterly composites of the charcoal cartridges are analyzed for iodine-129.

The monitoring system at the main plant stack is comprised of a set of nozzles and air monitoring transport line, independent of the sampler system, that isokinetically and continuously transports air samples to continuous air monitors (CAMs). The monitoring stream is wyed into both a beta CAM and an alpha CAM, which each have alarm setpoints that are set and maintained in accordance with environmental monitoring procedures.

The VF HVAC sampling and monitoring system is similar to the main plant stack sampling and monitoring system except that no sampling for tritium is performed.

There are nonradiological monitors in the Ex-Cell Off-Gas system to continuously measure concentrations of NH_3 slip and NO_x in the air exiting the catalytic reactors to the Main Plant stack. An analyzer for NO_x is connected upstream of the catalytic reactors and two analyzers, one for NO_x and one for ammonia, are connected downstream of the reactors. Both the NO_x and ammonia analyzer sampling lines are heat traced to prevent condensation within the line, which could affect the instrument readings. Continuous ammonia measurements are not required for the automated process control; therefore, no spare analyzers are required during brief ammonia analysis calibration operations. Bottles of analyzer calibration gases are located outside, at ground level, next to the 01-14 Building. Nonradiological monitors are not present for the VF HVAC system stack.

The stack-related alarm setpoints for NO_x, NH_3, alpha activity, and beta/gamma activity are set to allow for corrective actions to be taken to limit public and/or environmental exposures. The setpoint values are based on applicable normal operations release limits for radionuclides (40 CFR 61) and nonradiological source terms (6 NYCRR 212).

C.8.6.2 Analysis of Multiple Contribution

The WVDP will continue to measure the concentrations of radioactivity in all permitted air and liquid effluents from the site and to report the total calculated off-site doses in the Annual Site Environmental Reports. There are no other known sources of radioactive discharges in the WVDP environs.

C.8.6.3 Estimated Exposures from Routine Airborne Releases

Off-site exposures to radiation occur via atmospheric release of radioactive materials. Airborne emissions from the VF during normal operations come primarily from two sources. The Process Off-Gas system, which vents to the Main Plant stack, and the Vitrification Building HVAC system, which vents to the stack located on top of the Vitrification Building.

Emissions from the Process Off-Gas system and the Vitrification Building HVAC system were estimated using data provided in the mass balance spreadsheet (Crocker October 10, 1989) and element-specific partition coefficients developed during Functional and Checkout Testing of Systems (FACTS), which took place from 1984 to 1989 (Carl et al. September 30, 1990). (See Section C.9.4 as to why a more recent mass balance (Nixon

95) was not used for these calculations.) The Vitrification Cell is maintained at the greatest negative pressure (ventilation Zone I) relative to surrounding areas to ensure that all air leakage is into, rather than out of, the cell. The contaminated air from the Vitrification Cell is passed through two HEPA filters in series before being discharged from the Vitrification Building stack to the environment. The overall DF for this filtration was taken to be 1.0E+05. The DF for the first HEPA filter is 1,000, and the DF for the second HEPA filter is 100 (Elder 1986).

The quantity of radioactive material released to the environment from the Vitrification Building HVAC was estimated by assuming that 0.001% of the activity processed becomes airborne within the Vitrification Cell due to maintenance activities (U.S. Department of Energy December 1994). Based on the analyses performed, it was estimated that approximately 8.0E-04 Ci (comprised primarily of Cs-137, Sr-90, and their short-lived daughters Ba-137m and Y-90) are released to the environment during one year of operation.

The EDE to the maximally exposed off-site individual residing approximately 1,900 m (1.18 mi) north-northwest of the Vitrification Building stack due to routine atmospheric releases from the Vitrification Building HVAC system during one year of operation was determined to be 1.6E-05 mrem/yr in 1998.

The Process Off-Gas system maintains the SFCM under a negative pressure with respect to the Vitrification Cell. The system provides two types of particulate treatment. Wet scrubbing is used to remove particulates 1 micron (3.9E-05 in) and larger, and filtration is used for smaller (submicron) particles. Wet scrubbing, provided by the SBS, removes approximately 99% of the radioactivity and about 3% of the NO_x generated during the vitrification process. Gas exiting the SBS enters the mist eliminator, which removes liquid entrained in the gas as a result of the SBS treatment. This limits the liquid load at the HEME. The HEME is a glass mesh filter device used in commercial applications, and is capable of removal efficiencies above 95% for all particulate size ranges. The HEME is equipped with a spray wash so that the filter elements can be cleaned. The collected solution from the HEME is drained back to the SBS for recycling.

The in-cell portion of the Process Off-Gas system includes the vessel vent header and condenser, the SBS, a mist eliminator, a HEME, a heater, and a process prefilter consisting of two HEPA filters in series. Back-up HEME, heater, and prefilter units are available to allow maintenance or change of the filters. After treatment of the off-gas, it is sent to the ex-cell off-gas treatment and filtration equipment in the 01-14 Building via the Off-Gas Trench. The Process Off-Gas system is discussed in Sections C.6.3 and C.5.2.7.4.

Prior to the initiation of radioactive operations in the VF, the amount of radioactivity released from the Main Plant stack during one year of operation was estimated using Tank 8D-2 inventory and applying element-specific emission factors developed during FACTS testing. The results of this conservative release model estimated the EDE from expected emissions to the maximum exposed off-site individual to be 2.0E-01 mrem/yr (2.0E-03 mSv/yr). This estimated value can be compared to the actual 1995 Main Plant stack measurements, which when converted to a site boundary dose to the maximum exposed individual, results in 4.3E-04 mrem/yr (4.3E-06 mSv/yr). Because of the process off-gas release mechanisms in the vitrification operations, there has been an increase in release of Radon-220 and Iodine-131 from the WVDP Main Plant stack.

The principle sources of these releases are from the steam stripping operation in the CFMT during the concentration of HLW prior to its transfer to the MFHT and from the SBS connection to the Vessel Vent Header. After mist elimination, the off-gas receives two stage HEPA filtration and NO_x removal prior to release from the Main Plant stack. The transport time from the CFMT to the stack has been estimated to be approximately one minute, essentially equivalent to the Rn-220 half-life of 55 seconds, so that about half of the radon released gets to the stack. The radon is not removed by HEPA filtration and is not significantly soluble in water so that its removal is primarily due to decay.

Stack measurements during VF operation indicate that the daily release of Rn-220 averages approximately 9.5 curies per day. Similarly, the I-131 release is approximately 2E-07 curies per day. Based on these release rates, the EDE for the maximum exposed off-site individual has been calculated, utilizing the CAP-88 computer program and WVDP meteorology, to be 5.0E-02 mrem/yr (5.0E-04 mSv/yr) (Dames & Moore September 30, 1996) from radon and a negligible dose from I-131.

There are three normal operations related, nonradiological release sources from the Cold Chemical Building. These sources, or emission points, are:

- Solids Transfer system
- Vessel Vent system
- Dust Collection Hood

The principal releases from the Solids Transfer system occur during the VACUMAX transfer of solid chemical powders from 0.21-m^3 (55-gal) drums to Tanks 65-D-02, 65-D-03, and 65-D-04. The VACUMAX system is designed and engineered to release minimal quantities of particulate to the atmosphere in the Cold Chemical Building. Two filters in series are estimated to achieve an efficiency of 99.997% (New York State Department of Environmental Conservation January 8, 1992). The calculated emissions quantities are given in Table C.8.6.3-1.

The Cold Chemical Building Vessel Vent system includes nine tanks (65-D-01, 65-D-02, 65-D-03, 65-D-04, 65-D-05, 65-D-06, 65-D-07, 65-D-08, and 65-D-09), all of which are vented to the atmosphere through a Venturi Scrubber system. Inputs to these tanks are chemical powders or liquids. Based on a 99.2% scrubber efficiency for 0.1% of the mass of gases or particulates that are scrubbed, the overall fraction venting to the atmosphere is estimated to be 8.0E-06 of the quantity transferred (New York State Department of Environmental Conservation January 8, 1992). Table C.8.6.3-2 contains a list of the calculated emissions from the Vessel Vent system.

A dust collection hood is used in the west bay of the Cold Chemical Building for ventilation of dust resulting from material handling operations and for general ventilation purposes. Based on the temporary cold chemical test phase, it is estimated that less than 1.0E-03% of the amount of material transferred becomes airborne, with 50% becoming entrained in the dust collection hood. Emissions from the hood to the atmosphere are listed in Table C.8.6.3-3.

Because of high efficiencies of these systems in minimizing the quantities of material released to the atmosphere, normal operation releases of nonradiological materials pose no on-site or off-site threat.

The concentration of NO_x at the "maximum receptor" was calculated to be 9.2E-05 mg/m^3 (5.7E-12 lb/ft^3) (Roberts April 2, 1990), which is well below the 0.10 mg/m^3 (6.2E-09 lb/ft^3) National Ambient Air Quality Standard (NAAQS). The concentration of NH_3 at the "maximum receptor" was calculated to be 2.0E-06 mg/m^3 (1.2E-13 lb/ft^3) (Roberts April 2, 1990), which is well below the 0.36 mg/m^3 (2.2E-08 lb/ft^3) Ambient Guideline Concentration of New York State Air Guide-1. (The NAAQS does not provide guidelines for ammonia releases.)

C.8.6.4 Liquid Releases

Radioactive liquid wastes associated with the VF are processed through existing systems at the WVDP. Specifically, radioactive liquid wastes are either returned to the Waste Tank Farm for subsequent processing though the VF or Integrated Radwaste Treatment system (IRTS), or processed through the Low-Level Waste Treatment System (LLWTS) with subsequent release to the environment. The IRTS is discussed in other DOE approved WVDP safety documentation. The IRTS reduces activity levels so that the liquid can either be used in the Cement Solidification system or sent to the LLWTS. Discharges from the LLWTS are monitored, and annual individual and collective doses to the public are calculated. These doses typically are much less than one (1) mrem (0.01 mSv) to the maximally exposed off-site individual. Operation of the VF does not increase the annual dose from the liquid pathway substantially.

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Table C.8.2.1-1

List of Radionuclides that Contribute Greater Than 0.1% Of the Effective Dose Equivalent (EDE)
(In-Cell Off-Gas System)
June 1993

Nuclide	Total Curies[a]	Curies/Yr	DF per NRC[b]	Discharge Ci/Year
C-14	5.49E-01	1.83E-01	1.00E+00	1.83E-01
Sr-90	5.81E+06	1.94E+06	4.95E+09	3.91E-04
Tc-99	1.09E+02	3.63E+01	1.00E+04	3.63E-03
I-129	1.81E-01	6.02E-02	2.00E+00	3.01E-02
Cs-137	6.28E+06	2.09E+06	1.09E+08	1.92E-02
Ac-227	9.43E+00	3.14E+00	1.00E+09	3.14E-09
Pu-238	7.92E+03	2.64E+03	4.95E+09	5.33E-07
Pu-239	1.63E+03	5.42E+02	4.95E+09	1.09E-07
Pu-240	1.19E+03	3.98E+02	4.95E+09	8.04E-08
Pu-241	6.04E+04	2.01E+04	4.95E+09	4.07E-06
Am-241	5.36E+04	1.79E+04	4.95E+09	3.61E-06
Am-242m	2.89E+02	9.63E+01	4.95E+09	1.94E-08
Am-243	3.47E+02	1.16E+02	4.95E+09	2.33E-08
Cm-243	1.16E+02	3.86E+01	1.00E+09	3.86E-08
Cm-244	6.07E+03	2.02E+03	1.00E+09	2.02E-06

a) Note: Radionuclides content of Tank 8D-2.
b) Bixby April 11, 1990.

Table C.8.2.1-1

List of Radionuclides that Contribute Greater Than 0.1% Of the Effective Dose Equivalent (EDE)
(In-Cell Off-Gas System)
June 1993

Nuclide	Total Curies[a]	Curies/Yr	DF per NRC[b]	Discharge Ci/Year
C-14	5.49E-01	1.83E-01	1.00E+00	1.83E-01
Sr-90	5.81E+06	1.94E+06	4.95E+09	3.91E-04
Tc-99	1.09E+02	3.63E+01	1.00E+04	3.63E-03
I-129	1.81E-01	6.02E-02	2.00E+00	3.01E-02
Cs-137	6.28E+06	2.09E+06	1.09E+08	1.92E-02
Ac-227	9.43E+00	3.14E+00	1.00E+09	3.14E-09
Pu-238	7.92E+03	2.64E+03	4.95E+09	5.33E-07
Pu-239	1.63E+03	5.42E+02	4.95E+09	1.09E-07
Pu-240	1.19E+03	3.98E+02	4.95E+09	8.04E-08
Pu-241	6.04E+04	2.01E+04	4.95E+09	4.07E-06
Am-241	5.36E+04	1.79E+04	4.95E+09	3.61E-06
Am-242m	2.89E+02	9.63E+01	4.95E+09	1.94E-08
Am-243	3.47E+02	1.16E+02	4.95E+09	2.33E-08
Cm-243	1.16E+02	3.86E+01	1.00E+09	3.86E-08
Cm-244	6.07E+03	2.02E+03	1.00E+09	2.02E-06

a) Note: Radionuclides content of Tank 8D-2.
b) Bixby April 11, 1990.

Table C.8.3.4-1

Radiation Monitoring Equipment Typical Locations

Type*	Elevation	Location	Figure (Dwg. Number)
Vitrification Building			
CAMß-1, ARM-1	100 ft	West Operating Aisle	C.8.3.4-1 (905D-378S05A)
CAMß-2, ARM-2	100 ft	North Operating Aisle	C.8.3.4-1 (905D-378S05A)
CAMß-3, ARM-3, PF-4	100 ft	East Operating Aisle	C.8.3.4-1 (905D-378S05A)
ARM-13	100 ft	Diesel Room Area	C.8.3.4-1 (905D-378S05A)
ARM-15, PF-1, CAMß-11	100 ft	Southwest Corner (SFR)	C.8.3.4-1 (905D-378S05A)
PCM-1	100 ft	Northwest Stairwell	C.8.3.4-1 (905D-378S05A)
PCM-2	100 ft	Northeast Stairwell	C.8.3.4-1 (905D-378S05A)
PCM-3	110.25 ft	North Operating Aisle	C.8.3.4-2 (905D-378S06A)
CAMß-4, ARM-4	110.25 ft	West Operating Aisle	C.8.3.4-2 (905D-378S06A)
CAMß-5, ARM-5, PF-5	110.25 ft	North Operating Aisle	C.8.3.4-2 (905D-378S06A)
CAMß-6, ARM-6, PF-8	110.25 ft	East Operating Aisle	C.8.3.4-2 (905D-378S06A)
ARM-10	110.25 ft	Control Room	C.8.3.4-2 (905D-378S06A)
ARM-14, PF-7	110.25 ft	Southwest Corner (HVOS)	C.8.3.4-2 (905D-378S06A)
CAMß-7, ARM-7, PF-9	124 ft	West Operating Aisle	C.8.3.4-3 (905D-378S07A)
CAMß-8, ARM-8	124 ft	North Operating Aisle	C.8.3.4-3 (905D-378S07A)
CAMß-9, ARM-9, PF-10	124 ft	East Operating Aisle	C.8.3.4-3 (905D-378S07A)
CAMß-10, ARM-11 & 12, PF-11	131 ft	South Wall (CMR)	C.8.3.4-4 (905D-378S08A)

Table C.8.3.4-1 (Concluded)
Radiation Monitoring Equipment Typical Locations

Type*	Elevation	Location	Figure (Dwg. Number)
01-14 Building			
CAMß-1	130 ft	Process Filter Removal Room	C.8.3.4-7 (906D-378S02)
CAMß-2	124 ft	Off-Gas Treatment Room (Roof)	C.8.3.4-7 (906D-378S02)
CAMß-3	116.5 ft	Process Area	C.8.3.4-6 (906D-378S01)
CAMß-4	144 ft	Process Area	C.8.3.4-8 (906D-378S03)

* Type: CAM - Continuous Air Monitor - α, ß   ARM - Area Radiation Monitor
PCM - Personnel Contamination Monitor   PF - Personnel Frisker

Table C.8.6.3-1

Summary Table for Solids Transfer System

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Aluminum Hydroxide	7.72E-05	0.0806
Aluminum Nitrate	1.84E-04	0.1922
Aluminum Oxide	7.33E-05	0.0765
Barium Hydroxide Octahydrate	1.48E-05	0.0155
Barium Nitrate	1.23E-05	0.0128
Barium Oxide	7.33E-06	0.0077
Calcium Carbonate	2.34E-05	0.0244
Calcium Nitrate	3.83E-05	0.0400
Calcium Oxide	1.47E-05	0.0153
Cerium Hydroxide	8.87E-06	0.0093
Cerium Nitrate	1.65E-05	0.0173
Cerium Oxide	7.33E-06	0.0077
Chromium Oxide-Hydrate	4.32E-06	0.0045
Chromium Oxide	3.68E-06	0.0038
Cesium Hydroxide Monohydrate	4.37E-06	0.0046
Cesium Nitrate	5.07E-06	0.0053
Cesium Oxide	3.68E-06	0.0038
Copper Hydroxide	1.80E-06	0.0019
Copper Nitrate	3.48E-06	0.0036
Copper Oxide	1.47E-06	0.0015
Iron Oxide	1.47E-04	0.1531
Ferrous Nitrate	3.75E-04	0.3913
Potassium Hydroxide	5.95E-05	0.0622
Potassium Formate	9.17E-05	0.0958
Potassium Nitrate	1.07E-04	0.1122
Potassium Oxide	5.13E-05	0.0536

Table C.8.6.3-1 (Continued)
Summary Table for Solids Transfer System

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Lanthanum Oxide	7.33E-07	0.0008
Lithium Hydroxide Monohydrate	1.44E-04	0.1500
Lithium Formate	1.33E-04	0.1393
Lithium Nitrate	2.36E-04	0.2465
Lithium Oxide	5.13E-05	0.0536
Magnesium Hydroxide	1.97E-05	0.0206
Magnesium Nitrate	5.01E-05	0.0523
Magnesium Oxide	1.47E-05	0.0153
Manganese Oxide	1.80E-05	0.0188
Manganese Dioxide	3.70E-06	0.0039
Sodium Molybdate	2.10E-07	0.0002
Sodium Formate	3.53E-04	0.3687
Neodymium Oxide	2.20E-06	0.0023
Nickel Hydroxide	6.82E-06	0.0071
Nickel Nitrate	1.20E-05	0.0125
Nickel Oxide	5.50E-06	0.0057
Sodium Phosphate Monobasic	6.20E-05	0.0647
Sodium Sulfate	2.60E-05	0.0272
Silicon Oxide	2.79E-04	0.2908
Strontium Hydroxide	8.60E-06	0.0090
Strontium Nitrate	1.50E-05	0.0156
Strontium Oxide	7.33E-06	0.0077
Titanium Oxide	1.47E-05	0.0153
Zinc Oxide	7.33E-06	0.0077
Zirconium Oxide	3.68E-05	0.0384
Zirconium Hydroxide	4.74E-05	0.0495
Sodium Chloride	2.20E-06	0.0023
Sodium Fluoride	2.20E-06	0.0023

Table C.8.6.3-1 (Concluded)
Summary Table for Solids Transfer System

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Rhodium Oxide	2.20E-06	0.0023
Ruthenium Oxide	2.20E-06	0.0023
Palladium Oxide	2.20E-06	0.0023
Sucrose	1.48E-04	0.1545
Sodium Oxalate	3.48E-04	0.3633
Sodium Tetraborate Decahydr.	3.01E-04	0.3145
Boric Acid	1.95E-04	0.2039
Boric Oxide	1.10E-04	0.1148
Sodium Monoxide	9.95E-05	0.1039
Sodium Nitrate	2.73E-04	0.2850
Sodium Nitrite	2.22E-04	0.2313
IE-96/EI-95 (Zeolite)	1.32E-04	0.1378

Table C.8.6.3-2

Summary Table for Vessel Vent System

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Aluminum Hydroxide	2.06E-03	2.15
Aluminum Nitrate	4.91E-03	5.13
Aluminum Oxide	1.96E-03	2.04
Barium Hydroxide Octahydrate	3.95E-04	0.41
Barium Nitrate	3.27E-04	0.34
Barium Oxide	1.95E-04	0.20
Calcium Carbonate	6.23E-04	0.65
Calcium Nitrate	1.02E-03	1.07
Calcium Oxide	3.91E-04	0.41
Cerium Hydroxide	2.37E-04	0.25
Cerium Nitrate	4.41E-04	0.46
Cerium Oxide	1.95E-04	0.20
Chromium Oxide-Hydrate	1.16E-04	0.12
Chromium Oxide	9.74E-05	0.10
Cesium Hydroxide Monohydrate	1.16E-04	0.12
Cesium Nitrate	1.36E-04	0.14
Cesium Oxide	9.74E-05	0.10
Copper Hydroxide	4.78E-05	0.05
Copper Nitrate	9.19E-05	0.10
Copper Oxide	3.86E-05	0.04
Ferric Hydroxide	5.04E-03	5.27
Iron Oxide	3.91E-03	4.08
Ferrous Nitrate	9.99E-03	10.43
Potassium Hydroxide	1.59E-03	1.66
Potassium Formate	2.45E-03	2.55
Potassium Nitrate	2.86E-03	2.99

Table C.8.6.3-2 (Continued)
Summary Table for Vessel Vent System

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Potassium Oxide	1.37E-03	1.43
Lanthanum Oxide	2.02E-05	0.02
Lithium Hydroxide Monohydrate	3.83E-03	4.00
Lithium Formate	3.56E-03	3.71
Lithium Nitrate	6.30E-03	6.57
Lithium Oxide	1.37E-03	1.43
Magnesium Hydroxide	5.26E-04	0.55
Magnesium Nitrate	1.34E-03	1.39
Magnesium Oxide	3.91E-04	0.41
Manganese Oxide	4.80E-04	0.50
Manganese Dioxide	9.92E-05	0.10
Sodium Molybdate	5.51E-06	0.01
Sodium Hydroxide	3.42E-03	3.58
Sodium Formate	9.42E-03	9.83
Neodymium Oxide	5.88E-05	0.06
Nickel Hydroxide	1.82E-04	0.19
Nickel Nitrate	3.20E-04	0.33
Nickel Oxide	1.47E-04	0.15
Sodium Phosphate Monobasic	1.65E-03	1.72
Phosphoric Acid	1.41E-03	1.48
Sodium Sulfate	6.95E-04	0.73
Silicon Oxide	7.43E-03	7.76
Strontium Hydroxide	2.30E-04	0.24
Strontium Nitrate	3.99E-04	0.42
Strontium Oxide	1.95E-04	0.20
Titanium Oxide	3.91E-04	0.41
Zinc Oxide	1.95E-04	0.20
Zirconyl Nitrate, hydrate	2.12E-03	2.21

Table C.8.6.3-2 (Concluded)
Summary Table for Vessel Vent System

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Zirconium Oxide	9.78E-04	1.02
Zirconium Hydroxide	1.26E-03	1.32
Sodium Chloride	5.88E-05	0.06
Sodium Fluoride	5.88E-05	0.06
Rhodium Oxide	5.88E-05	0.06
Ruthenium Oxide	5.88E-05	0.06
Palladium Oxide	5.88E-05	0.06
Sucrose	3.95E-03	4.12
Sodium Oxalate	9.28E-03	9.69
Formic Acid	6.37E-03	6.65
Sodium Tetraborate Decahydr.	8.03E-03	8.39
Boric Acid	5.21E-03	5.44
Boric Oxide	2.93E-03	3.06
Sodium Monoxide	2.66E-03	2.77
Sodium Nitrate	7.28E-03	7.60
Sodium Nitrite	5.91E-03	6.17
Nitric Acid	7.95E-03	8.30
IE-96/EI-95 (Zeolite)	3.52E-03	3.67

Table C.8.6.3-3

Summary Table for Dust Collection Hood

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Aluminum Hydroxide	1.29E-05	1.34E-02
Aluminum Nitrate	3.07E-05	3.20E-02
Aluminum Oxide	1.22E-05	1.28E-02
Barium Hydroxide Octahydrate	2.47E-06	2.58E-03
Barium Nitrate	2.05E-06	2.14E-03
Barium Oxide	1.22E-06	1.28E-03
Calcium Carbonate	3.89E-06	4.06E-03
Calcium Nitrate	6.38E-06	6.67E-03
Calcium Oxide	2.44E-06	2.55E-03
Cerium Hydroxide	1.48E-06	1.54E-03
Cerium Nitrate	2.76E-06	2.88E-03
Cerium Oxide	1.22E-06	1.28E-03
Chromium Oxide-Hydrate	7.20E-07	7.51E-04
Chromium Oxide	6.11E-07	6.38E-04
Cesium Hydroxide Monohydrate	7.28E-07	7.60E-04
Cesium Nitrate	8.45E-07	8.82E-04
Cesium Oxide	6.11E-07	6.38E-04
Copper Hydroxide	3.00E-07	3.13E-04
Copper Nitrate	5.79E-07	6.05E-04
Copper Oxide	2.44E-07	2.55E-04
Iron Oxide	2.44E-05	2.55E-02
Ferrous Nitrate	6.25E-05	6.52E-02
Potassium Hydroxide	9.92E-06	1.04E-02
Potassium Formate	1.53E-05	1.60E-02
Potassium Nitrate	1.79E-05	1.87E-02
Potassium Oxide	8.55E-06	8.93E-03

Table C.8.6.3-3 (Continued)
Summary Table for Dust Collection Hood

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Lanthanum Oxide	1.22E-07	1.28E-04
Lithium Hydroxide Monohydrate	2.40E-05	2.50E-02
Lithium Formate	2.22E-05	2.32E-02
Lithium Nitrate	3.94E-05	4.11E-02
Lithium Oxide	8.55E-06	8.93E-03
Magnesium Hydroxide	3.28E-06	3.43E-03
Magnesium Nitrate	8.35E-06	8.71E-03
Magnesium Oxide	2.44E-06	2.55E-03
Manganese Oxide	2.99E-06	3.13E-03
Manganese Dioxide	6.17E-07	6.44E-04
Sodium Molybdate	3.50E-08	3.65E-05
Sodium Formate	5.89E-05	6.14E-02
Neodymium Oxide	3.67E-07	3.83E-04
Nickel Hydroxide	1.14E-06	1.19E-03
Nickel Nitrate	2.00E-06	2.08E-03
Nickel Oxide	9.16E-07	9.57E-04
Sodium Phosphate Monobasic	1.03E-05	1.08E-02
Sodium Sulfate	4.34E-06	4.53E-03
Silicon Oxide	4.64E-05	4.85E-02
Strontium Hydroxide	1.43E-06	1.50E-02
Strontium Nitrate	2.50E-06	2.61E-03
Strontium Oxide	1.22E-06	1.28E-03
Titanium Oxide	2.44E-06	2.55E-03
Zinc Oxide	1.22E-06	1.28E-03
Zirconium Oxide	6.12E-06	6.39E-03
Zirconium Hydroxide	7.90E-06	8.25E-03
Sodium Chloride	3.67E-07	3.83E-04
Sodium Fluoride	3.67E-07	3.83E-04

Table C.8.6.3-3 (Concluded)
Summary Table for Dust Collection Hood

Contaminant	Hourly Emissions (lbs/hr)	Annual Emissions (lbs/yr)
Rhodium Oxide	3.67E-07	3.83E-04
Ruthenium Oxide	3.67E-07	3.83E-04
Palladium Oxide	3.67E-07	3.83E-04
Sucrose	2.47E-05	2.58E-02
Sodium Oxalate	5.80E-05	6.05E-02
Sodium Tetraborate Decahydr.	5.02E-05	5.24E-02
Boric Acid	3.25E-05	3.40E-02
Boric Oxide	1.83E-05	1.91E-02
Sodium Monoxide	1.66E-05	1.73E-02
Sodium Nitrate	4.55E-05	4.75E-02
Sodium Nitrite	3.69E-05	3.86E-02
IE-96/EI-95 (Zeolite)	2.20E-05	2.30E-02

C.9.0 HAZARD AND ACCIDENT ANALYSIS

C.9.1 Introduction

This chapter discusses the hazard classification of the Vitrification Facility (VF), the Process Hazard Analysis (PHA), and analyses of Evaluation Basis Accidents (EBAs), the Design Basis Earthquake (DBE), the Design Basis Tornado (DBT), and consideration of beyond-design-basis events. Section C.9.1.1 provides the Evaluation Guidelines (EGs) that are used to judge whether or not the Vitrification Facility (VF) affords adequate protection for the public and on-site workers. The analyses described in Sections C.9.4 and C.9.5 demonstrate that, for all credible accidents, the Evaluation Guidelines would be met without operator intervention or High Efficiency Particulate Air (HEPA) filtration.

There are several documents containing technical guidelines/criteria that provide a common basis for the hazard and accident analyses described in this chapter. These documents, which support the basic requirements in U.S. Department of Energy (DOE) Order 5480.23, include DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports* (U.S. Department of Energy July 1994), and DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* (U.S. Department of Energy December 1992). On a more technical level, the DOE Handbook DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, (U.S. Department of Energy December 1994) has been used for accident release parameters.

C.9.1.1 WVDP Evaluation Guidelines (EGs)

To facilitate the development of safety analysis evaluation guidelines for hazards associated with WVDP facilities, several distinctions have been made. These distinctions are as follows:

1) Whether the event (accident) is manmade or caused by natural phenomena;

2) Whether the hazard is radiological or toxicological; and

3) Whether the population at risk is the public or on-site workers.

These distinctions lead to eight different combinations for which an evaluation guideline is required. This Section establishes evaluation guidelines for these eight situations, and provides the justifications and precedents on which the guidelines are based.

For manmade accidents with either internal or external initiators, radiological EBAs are compared to EGs over the frequency spectrum of 0.1 to 1E-06 events per year. Toxicological EBAs are compared to EGs based on Secretary of Energy Notice (SEN)-35-91 over the frequency spectrum 0.1 to 1E-04 per year.

Public Radiological EG

Manmade EBAs shall not cause doses to the maximally exposed off-site individual (MOI) greater than: (1) 0.5 rem (5.0E-03 Sv) for accidents with estimated frequencies < 0.1 per year but ≥ 1E-02 per year; (2) 5 rem (0.05 Sv) for accidents with estimated frequencies < 1E-02 per year but ≥ 1E-04 per year; and (3) 25 rem (0.25 Sv) for accidents with estimated frequencies < 1E-04 per year but > 1E-06 per year. Manmade EBAs with estimated frequencies ≤ 1E-06 per year are not considered credible.

Public Toxicological EG

For manmade EBAs with an estimated frequency of < 0.1 per year but ≥ 1E-04 per year, the risk of prompt fatality to an average individual in the vicinity of the WVDP from accidents shall not exceed one-tenth of one percent (0.1%) of the sum of prompt fatalities resulting from other accidents to which members of the population are generally exposed. For evaluation purposes, individuals are assumed to be located within one mile of the site boundary.

On-Site Radiological EG

Manmade EBAs shall not result in calculated doses at the on-site evaluation point (OEP) (640 meters) greater than: (1) 5 rem (0.05 Sv) for accidents with estimated frequencies < 0.1 per year but ≥ 1E-02 per year; (2) 25 rem (0.25 Sv) for accidents with estimated frequencies < 1E-02 per year but ≥ 1E-04 per year; and (3) 100 rem (1.0 Sv) for accidents with estimated frequencies of < 1E-04 per year but > 1E-06 per year. Manmade EBAs with estimated frequencies ≤ 1E-06 per year are not considered credible.

On-Site Toxicological EG

On-site numerical EGs shall not be required for safety assurance in the analysis of manmade accidents.

Natural phenomena-induced EBAs with initiating frequencies defined by applicable design criteria documents are compared against the following EGs.

Public Radiological EG

Natural phenomena induced EBAs shall not cause doses to the MOI greater than 25 rem (0.25 Sv).

Public Toxicological EG

The risk to an average individual in the vicinity of the WVDP for prompt fatalities that might result from natural phenomena induced EBAs shall not exceed one-tenth of one percent (0.1%) of the sum of prompt fatalities resulting from other accidents to which members of the population are generally exposed. For evaluation purposes, individuals are assumed to be located within one mile of the site boundary.

On-Site Radiological EG

On-site numerical EGs shall not be required for safety assurance in the analysis of accidents induced by natural phenomena.

On-Site Toxicological EG

On-site numerical EGs shall not be required for safety assurance in the analysis of accidents induced by natural phenomena.

C.9.1.1.1 Justification for Selected EGs for Public Exposure

Public Radiological EGs for Manmade Accidents

These radiological guidelines define public dose limits based on frequency ranges for both internally and externally initiated manmade accidents. The approach described here has the following advantages: (1) it is less burdensome with regard to frequency determinations than a continuous function of allowable dose versus frequency; (2) it is a simpler vehicle for judging acceptability when frequency estimates are called into question; and (3) it is consistent with precedents in the American National Standards Institute (ANSI)/ American Nuclear Society (ANS) Standard 51.1, *Nuclear Safety Criteria for Design of Stationary Pressurized Water Reactor Plants*. Using the step function method, a scenario can be shifted easily to the next range for comparison when it approaches the limit of a frequency range or when its frequency has been called into doubt.

For the estimated accident frequency range from 0.1 to 0.01 per year (anticipated events), the acceptable accident dose at the site boundary is 0.5 rem (5.0E-03 Sv). This limit is derived from DOE Order 5400.5, which states:

> The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent of greater than 100 mrem...if avoidance of the higher exposures is impracticable, the Operations Office may request, from EH-1, specific authorization for a temporary public dose limit higher than 100 mrem but not to exceed 500 mrem...if the dose averaged over a lifetime dose not exceed the principal limit of 100 mrem (U.S. Department of Energy February 8, 1990).

The 500 mrem (5.0 mSv) value is below both the 2.5 rem (0.025 Sv) value recommended by ANS Standard 51.1, and the 1 rem (0.01 Sv) value recommended as a protective action guideline (PAG) in DOE's *Emergency Management Guide for Hazards Assessment* (U.S. Department of Energy June 1992). Given the frequency of only one event in ten to one hundred years, the acknowledgment in DOE Orders that a 500 mrem (5.0 mSv) value can be accepted for routine operations, which are much more limiting than accident conditions, and the fact that ANSI/ANS and DOE Emergency Management guidance recommends even higher values, 0.5 rem (5.0E-03 Sv) is a conservative and reasonable guideline.

For the estimated range from 1E-02 to 1E-04 events per year (unlikely events), the acceptable accident dose at the site boundary is 5 rem (0.05 Sv), a value equal to the 10 CFR 72 bounding consequence limit for DBAs at independent spent fuel storage facilities. This value is also recommended as a protective action guideline in DOE's *Emergency Management Guide for Hazards Assessment* when the 0.5 rem (5.0E-03 Sv) value is considered too restrictive for releases dominated by 50-year committed effective dose equivalent (CEDE) doses from alpha emitters. This is the case for WVDP facilities and operations.

For the estimated frequency range from 1E-04 to 1E-06 events per year (extremely unlikely events), the acceptable accident dose at the site boundary is 25 rem (0.25 Sv). This value has historical precedent both as a siting criteria referenced in DOE Order 6430.1A, *General Design Criteria*, and as a design basis acceptance criteria for reactor siting in 10 CFR 100. Contribution to the dose is dominated by prompt exposure for the 10 CFR 100 calculation from which the DOE references were derived. As such, the number is extremely conservative for the WVDP, where the 50-year inhalation dose from alpha emitters is predominant. A total effective dose equivalent (TEDE) of 25 rem (0.25 Sv) primarily from inhaled alpha emitters would not produce a prompt effect comparable to the effect of 25 rem (0.25 Sv) received in a short time, although 25 rem (0.25 Sv) would not produce significant acute effects even if it resulted from a prompt dose.

Events with frequencies less than or equal to 1E-06 per year are considered to be incredible, and those with frequencies greater than 0.1 events per year are considered an aspect of normal operations, which are conducted so that annual releases remain within established limits prescribed by both the DOE and the U.S. Environmental Protection Agency (EPA). The 1E-06 event per year threshold is used for conservative frequency estimations.

The concept of a step function for dose limits is in keeping with the precedent set by ANSI/ANS 51.1. A dose comparison between this standard and WVDP guidelines is presented as Table C.9.1.1.1-1. The accidents against which these guidelines are individually compared are the significant accidents determined from hazard evaluation for all frequency ranges.

Public Radiological EGs for Natural Phenomena Accidents

The radiological guideline for natural phenomena, such as seismic events, is 25 rem (0.25 Sv) TEDE to the MOI for single evaluation basis events. The 25 rem (0.25 Sv) value used by the Nuclear Regulatory Commission (NRC) as a siting criterion (10 CFR 100) is accepted because it is a prompt dose at which no significant health effects will be experienced by the MOI.

Some WVDP facilities do not have documented design basis events against which continued facility functionality can be demonstrated (e.g., the Main Plant). This is a significant problem with regard to seismic events, which have the capability to breach all facility barriers because of the significant physical damage they can cause to a structure. The following discussion focuses on seismic events, but is considered applicable to any natural phenomena event.

It is difficult to demonstrate facility functionality following an earthquake with a given return frequency because of the uncertainty in assigning a given ground acceleration to a specific frequency. This task also is made difficult by a lack of documentation of facility construction details to the degree necessary to reach conclusions that are defensible to independent reviewers. For the purposes of safety analysis, a facility should be examined against a specific acceleration associated with a given frequency of occurrence in the facility region (0.1 g for the WVDP). However, the earthquake cannot be thought of as a true design basis earthquake for older facilities whose construction pre-dates the establishment of the DBE. Instead, it is an evaluation basis earthquake against which structural responses are examined in order to estimate potential impacts on the public. If the dose to the MOI meets the guidelines, then the facility is considered not to present a significant risk to the public due to seismic events.

Any seismic event with a return frequency less than the frequency of the DBE is considered a beyond design basis event. Any accidents based on design basis natural phenomena that involve additional damage/events not directly caused by a natural phenomenon, highly unlikely damage configurations, or unlikely synchronization of damage also are considered beyond the design basis. To clarify this second condition, several examples are discussed. First, consider an ammonia storage tank located directly outside a facility. If the seismic criterion was 0.1 g with a factor of 10 conservatism in evaluation, and the storage tank met this criterion, then an accident scenario which included the earthquake plus failure of the storage tank would be beyond the design basis.

Another example would be a storage area for three units of fissile material. Suppose criticality calculations indicated that, in the aftermath of an earthquake causing facility damage, criticality would occur if the units were driven together, bent into concentric cylinders, and the area then was flooded to provide moderation. This sequence of events would have produced a highly unlikely damage configuration as well as an unlikely synchronization of events. Therefore, this accident would be considered beyond the design basis. Similarly, consider a facility that has substantial damage from an earthquake and has combustible hydraulic oil in a room located 76.2 m (250 ft) from a large vault with plutonium. The operations are unrelated, and when the oil is spread to a depth of 25 mm (1 in), it only covers an area of 18.6 m^2 (200 ft^2). Devising a means to get the oil to the vault to create a fire in the vault would be a highly unlikely configuration and thus beyond design basis. If the oil is the only concentrated source of combustibles, a large fire sweeping through the entire remains of the building and burning all radionuclides would also be beyond design basis.

The second set of conditions for designating beyond design basis events is not intended to avoid considering events such as fires in concurrence with earthquakes. They are intended to cover the addition of an earthquake to an event such as a fire or an explosion, where the second event is not due to a clear, reasonable common cause. Expending resources on a large number of very low probability accident combinations does nothing to improve safety. Therefore, earthquakes in combination with events that are not realistically initiated by earthquakes have not been analyzed.

Public Radiological EGs Compared to SEN-35-91

DOE policy, established in Secretary of Energy Notice (SEN)-35-91, *Nuclear Safety Policy*, is that no individual shall be exposed to significant additional risk to health and safety from the operation of a DOE nuclear facility beyond the risks to which members of the general population are normally exposed. To that end, DOE has stated in SEN-35-91 two quantitative safety goals to limit public risk. The two goals, originally established by the NRC for the commercial nuclear power plant industry, are considered to be "aiming points for performance." These goals are:

- The risk to an average individual in the vicinity of a DOE nuclear facility for prompt fatalities that might result from accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatalities resulting from other accidents to which members of the population are generally exposed. For evaluation purposes, individuals are assumed to be located within one mile of the site boundary.

- The risk to the population in the area of a DOE nuclear facility for cancer fatalities that might result from operations should not exceed one-tenth of one percent (0.1%) of the sum of all cancer fatality risks resulting from all other causes. For evaluation purposes, individuals are assumed to be located within 16.1 km (10 mi) of the site boundary.

The minimum prompt whole body radiation dose that might be fatal to the most sensitive members of the population is generally assumed to be 100 rem (1.0 Sv). Prompt doses fatal to 50% of an exposed population typically are estimated to range from 200 to 400 rem (2.0 to 4.0 Sv). Since all of the off-site radiological EGs are well below the 100 rem (1.0 Sv) value, the prompt fatality nuclear safety goal easily will be met by facilities adhering to the proposed EGs.

The latent cancer fatality safety goal can be expressed mathematically as:

$$R_{fac.} \leq 1E-03 * R_{can.}$$

where $R_{fac.}$ = cancer fatality risk to an average individual due to the DOE facility, and

$R_{can.}$ = cancer fatality risk to an average individual due to all other causes.

The value for the cancer fatality risk to an average individual due to all other causes, $R_{can.}$, is approximately 2E-03 per year. This value is based on cancer death rate statistics reported by the National Safety Council. This result is an expected value, averaged over the entire population of the United States. Its application to the safety goal population (i.e., the population within 16.1 km (10 mi) of the site boundary) assumes that the average cancer fatality rate around the facility is the same as the national average. Although regional variations in cancer fatality rates have been identified, their causes are not well understood, and the value of 2E-03 per year has extensive precedent for safety goal calculations. Accordingly, the maximum facility risk that will meet the latent cancer facility safety goal is 2E-06 latent cancer fatalities per person per year.

The current estimate (from the International Commission on Radiological Protection, Report No. 60 [1990]) of fatal cancer induction due to low-level radiation exposure to the general population is 5E-04 latent cancer fatalities per rem. Dividing the latent cancer safety goal risk by this estimate expresses the safety goal in terms of dose as 4 mrem (0.04 mSv) per person per year. This is the risk, expressed in dose, that DOE considers acceptable for the average individual located within 16.1 km (10 mi) of the site boundary. The dose defined by this risk expression cannot be directly compared to the theoretical MOI doses making up the off-site EGs.

The average individual dose in the site environs typically is considered to be three to four orders of magnitude less than the MOI dose. Data presented in the *Defense Programs Safety Survey Report* for five DOE sites indicates that, in general, at least two orders of magnitude separate the MOI and average individual dose even for unusual configurations. Using this lower estimate for a generic example defines 400 mrem (4.0 mSv) per year as the MOI dose that will satisfy the safety goal. Further, the original NRC safety goal, which has been adopted by DOE, was based on a calculated mean value dose as opposed to a more conservative dose estimate. The difference between mean and 95% values of relative dispersion alone is typically at least a factor of two. Based on the conservatism built into the methodology adopted for these accident analyses, it is estimated that a MOI doses of 1000 mrem (10.0 mSv) per year could result from DOE operations without exceeding the latent cancer safety goal as it is applied to the population within 16.1 km (10 mi) of the site.

What type of accident spectrum is allowable to meet this conservative estimate? An initial examination will focus on the frequency ranges of the EGs. The first range spans from 1 event in 10 years to 1 event in 100 years. To meet the conservative safety goal limit of a cumulative 1000 mrem/yr (10.0 mSv/yr) MOI exposure for the 0.5 rem (5.0E-03 Sv) range of the step function, an accident causing an MOI dose of 0.5 (5.0E-03 Sv) rem could be specified every 1.25 years from the 10 year point (0.1 event per year) to the 100 year point (0.01 event per year). This would correspond to an identified accident with a consequence of 0.5 rem (5.0E-03 Sv) at 0.1 event per year, 0.089 event per year, 0.08 event per year and so on, for a total of 72 such events in the anticipated accident range. For a simpler example, 20 0.5-rem (5.0E-03 Sv) events could be identified at a frequency of 0.1 event per year to meet an overall total of 1000 mrem/yr (10.0 mSv/yr). Existing DOE operating experience clearly indicates neither of these examples are credible.

The 5 rem (0.05 Sv) range of the EG step function spans from 1 event in 100 years to 1 event in 10,000 years. In the same manner as noted above, an accident causing an MOI dose of 5 rem (0.05 Sv) could be identified every 25 years over the range of 0.01 event per year to 1 E-4 event per year to meet the conservative summation goal of 1000 mrem/yr (10.0 mSv/yr). This would correspond to an identified accident with a consequence of 25 rem (0.25 Sv) at 0.01 event per year, 0.008 event per year, 0.0067 event per year and so on, for a total of almost 400 such events in the unlikely accident range. For a simpler example, as above, 20 5-rem (0.05-Sv) events could be identified at a frequency of 0.01 event per year to meet an overall total of 1000 mrem/yr (10.0 mSv/yr).

For the 25 rem (0.25 Sv) range of the EG step function, identifying an accident causing an MOI dose of 25 rem (0.25 Sv) every 100 years (almost 10,000 events) over the range of 1 E-4 event per year to 1 E-6 event per year will only result in a cumulative MOI dose of approximately 120 mrem (1.2 mSv). Four hundred 25-rem (0.25-Sv) events can occur at a frequency of 1E-4 events per year to equal the conservative summation goal of 1000 mrem/yr (10.0 mSv/yr).

For an example combining the ranges, accidents matching EG dose limits were assumed to be identified every 10 years over the range of 0.1 event per year to 0.01 event per year, every 100 years over the range of 0.01 event per year to 1 E-4 event per year, and every 1000 years over the range 1 E-4 event per year to 1 E-6 event per year. Additionally, a single point natural phenomena event causing an MOI dose of 25 rem (0.25 Sv) was assumed at a frequency of 0.01 event per year. The cumulative MOI dose for these events was approximately 770 mrem (7.7 mSv).

The conservative nature of the EGs is apparent from the data shown in Table C.9.1.1.1-2. For a single accident point comparison, the MOI doses would meet the safety goal assuming that there are two orders of magnitude difference between the MOI and the average individual dose.

The *Defense Programs Safety Survey Report* concludes that the large doses indicated at the lower end of the frequency spectrum are not obtainable at virtually any non-reactor nuclear facility, either individually or in summation from available initiators. With over 1000 years of cumulative facility operating experience, DOE has yet to experience accidents producing the minimum EG dose of 500 mrem (5.0 mSv) at the site boundary. Analyses to date have also not estimated such consequences at high frequencies. However, using the population dose calculations based on actual site geometries and off-site populations, the *Defense Programs Safety Survey Report* estimated that for all types of non-reactor nuclear facilities except tritium facilities, bounding consequence accidents could typically occur with frequencies greater than one in 10 events per year and still meet the latent cancer fatality safety goal.

This information provides confidence that a facility meeting the EGs stated herein can be expected to meet the DOE latent cancer fatality safety goal.

<u>Public Toxicological EGs for Natural Phenomena and Manmade Accidents</u>

The WVDP EGs for exposure of the public to toxicological hazards resulting from natural phenomena and manmade accidents are derived from the risk- based safety goals stated in SEN-35-91. The safety goal for limiting cancer risk in SEN-35-91 has not been incorporated because the non-radioactive hazardous materials primarily are a threat to human health because of their acute toxicity, not their cancer-causing potential. The 1E-04 per year frequency demarcation between an accident that is considered to be within design basis and one that is beyond design basis is based on established guidance provided by the Federal Emergency Management Agency, Environmental Protection Agency, and Department of Transportation (March 21, 1989). It is noted that the annual frequency of design basis natural phenomena events, particularly earthquakes, is often within the range of 0.1 to 1E-04 events per year.

C.9.1.1.2 Justification for Selected EGs for Workers

On-Site Radiological EGs for Manmade Accidents

The WVDP has adopted the same conceptual approach for on-site EGs as for EGs that are applicable to the public. However, on-site EGs are greater than those for the public for a variety of reasons, not the least of which is because the Project has accepted the basic premise that entry onto the site implies acceptance of a higher degree of risk than that which the public would accept. This is considered acceptable with regards to worker safety because the guideline doses at the on-site evaluation point (OEP) (640 m [2,100 ft]) would not result in any noticeable acute health effects to exposed individuals at accident frequencies ≥ 1E-04 per year.

A three-tiered step function is again used for internal and external manmade accidents. For accidents with an estimated frequency between 0.1 and 1E-02 per year, the guideline is 5 rem (0.05 Sv) based on the allowable yearly worker exposure limits cited in 10 CFR 835, *Occupational Radiation Protection*, (U.S. Department of Energy). For the frequency range of 1E-02 to 1E-04 per year, the criterion is 25 rem (0.25 Sv) for the same reason the NRC provided in 10 CFR 100 for using it for design basis reactor accident calculations (i.e., it is a dose that causes no significant health effects).

Potential guideline values for the least frequent range of 1E-04 to 1E-06 events per year were examined in detail. The guideline values used by WVDP are expressed in units of rem. However, the historical information available for evaluating this issue is expressed in units of rads. For beta- and gamma-emitters, a rad is essentially equivalent to a rem. For alpha emitters, such as plutonium, the conversion is not as simple and depends on the quality factor. However, the limits imposed on doses due to alpha radiation are for cumulative 50-year doses, not prompt doses. No acute affects will be associated with such doses at the levels discussed.

The NRC report WASH-1400, *Reactor Safety Study*, compiled extensive information for acute effects of prompt doses in the mid-1970's. This document estimated that in the absence of medical treatment, a prompt dose on the order of 200 rad would prove fatal for 1% of the population within 60 days. A prompt dose on the order of 140 rad was estimated fatal to 0.01% of the populations within 60 days. A number of textbooks have also standardized discussion of acute effects. Two examples from the early 1980's are *Basic Nuclear Engineering* (Foster, A. R., Allyn and Bacon, Inc., 1983, ISBN# 0-205-07886-9) and *Introduction to Nuclear Engineering* (Lamarsh, J. R., Addision-Wesley Publishing Company, 1983, ISBN# 0-201-14200-7). The first text estimates no noticeable effects from doses below 100 rad. For doses between 100 and 200 rad, it estimates no deaths, but acknowledges the possibility of transient weakness and vomiting in 5% to 50% of the population. The second text estimates no observable effects beyond minor chromosomal aberrations and temporary depression of the white blood cell count for acute doses less than 75 rem (0.75 Sv). For doses between 75 and 200 rem (0.75 and 2.0 Sv), it estimates no fatalities, but acknowledges the possibility of vomiting in 5% to 50% of the exposed population, with accompanying fatigue and loss of appetite. Complete recovery is expected within a few weeks.

A more recent assessment is provided as an attachment to the *EPA Manual of Protective Action Guides for Protective Actions for Nuclear Incidents* (EPA-400-R-92-001 [U.S. Environmental Protection Agency May 1992). The estimations in this document were conservative in keeping with its purpose, which was to establish protective action guidelines for emergency planning. A dose of 300 rad was assumed to be fatal to 50% of the exposed population and used as the basis for extrapolation to two standard deviations. No estimates were made below 5% fatality and above 95% fatality, so these values comprise the starting and ending points for estimation. Doses less than 140 rad were listed as having no fatalities, although this estimation was caveated with the statement "the risk of fatality below 140 rad is not necessarily zero, rather it is indeterminate and likely to remain so." A dose of 140 rad was the starting point for estimation and was assigned the 5% fatality value. A dose of 200 rad was assumed to cause 15% fatality, an estimate significantly greater than those cited in the preceding paragraph.

For prodromal effects such as vomiting and fatigue, the EPA report estimated effects by the following simple analogy:

> For moderately severe prodromal (forewarning) effects, we believe the dose at which the same percentage of exposed would show effects would be approximately half of that causing fatality.

Accordingly, 100 rad was estimated as the dose at which 15% of the population would experience moderately severe effects since 200 rad was the dose at which 15% fatality was estimated. Fifty rad was the lower limit at which it was believed less then 2% of the population would experience effects. The caveat applied to the 140 rad, no fatality estimate was also applied to this value.

The DOE *Emergency Management Guide for Hazards Assessment* (June 1992) uses 100 rem (1.0 Sv) whole body exposure as a threshold for early severe effects. It also acknowledges that early severe effects would not actually be experienced for a 50-year dose of 100 rem (1.0 Sv) due to alpha emitters.

Based on the data discussed above, a value of 100 rem (1.0 Sv) was deemed appropriate and hence designated as the evaluation guideline for accidents in the frequency range of 1E-04 to 1E-06 per year.

On-Site Radiological and Toxicological EGs for Natural Phenomena Accidents

The risk to workers from severe natural phenomena is considered to be dominated by the structural response of their own facility rather than by radionuclide and/or chemical releases. The basis for this rationale is that failure of a given facility's structures, systems, and components (SSCs) is likely to kill and/or injure workers during the event itself as opposed to exposing them to an unspecified, but survivable, concentration of radioactivity or hazardous chemical as a result of failure of the facility's SSCs or some other (nearby) facility's SSCs. Hence, the WVDP considers that resources to enhance worker safety are more properly focused on examination of individual building survivability. Also regarding on-site radiological and toxicological EGs for natural phenomena accidents, the WVDP concurs with the statement from DOE-STD-3009-94 that *On-site Evaluation Guidelines* are not required for adequate documentation of a safety basis utilizing the overall process of this Standard.

On-Site Toxicological EGs for Manmade Accidents

Regarding on-site toxicological EGs for manmade accidents, as noted above, the WVDP concurs with the statement from DOE-STD-3009-94 that *On-site Evaluation Guidelines* are not required for adequate documentation of a safety basis utilizing the overall process of this Standard. Additionally, the WVDP subscribes to the DOE-STD-3009-94 position of emphasizing the role of Process Safety Management (PSM) as defined in 29 CFR 1910.119 in minimizing worker risk. DOE-STD-3009-94 states the following:

> The Occupational Health and Safety Administration (OSHA) has recently published 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*. The purpose of this regulation is defined by OSHA in summary fashion as, "Employees have been and continue to be exposed to the hazards of toxicity, fires, and explosions from catastrophic releases of highly hazardous chemicals in their workplaces. The requirements of this standard are intended to eliminate or mitigate the consequences of such releases." Many of the topics requiring coverage in this federal regulation, such as design codes and standards, process hazard analysis, human factors, training, etc., are directly parallel to the topics addressed by DOE 5480.23. The regulation also provides overall

integration of these topics. The OSHA standard addresses the issue of worker safety from process accidents by requiring the performance of hazard analyses for processes (exclusive of standard industrial hazards) in conjunction with implementation of basic safety programs that discipline operations and ensure judgments made in hazard analyses are supported by actual operating conditions. These requirements effectively integrate programs and analyses into an overall safety management structure without requiring quantitative risk assessment.

In the analysis of radiological accidents presented in Section C.9.4, a respirable fraction of one (1) was assumed in order to ensure that inhalation dose estimates are conservative. For the specific purpose of comparing the calculated radiation doses from hypothetical accidents to the Evaluation Guidelines described above, no credit was taken for any HEPA filtration or for intervention by operating personnel.

C.9.2 Hazard Classification

Assignment of the VF to an appropriate hazard category is based on the guidance provided in DOE-STD-1027-92. This document defines a Category 2 facility as a facility having the potential for significant on-site consequences requiring emergency planning. A basis for estimating this potential is provided in the form of a list of threshold quantities of various nuclides whose unmitigated release could cause a substantial radiation dose on-site. As stated in DOE-STD-1027-92, "if a fuel reprocessing plant has more than 1,000 Ci of mixed fission products, it is a Category 2 facility with no need to consider individual radionuclide make-up". Because the total inventory of radioactivity in the VF generally will exceed 1,000 Ci, it clearly is a Category 2 facility. No additional analysis is required in order to establish that this is the correct classification.

C.9.3 Process Hazard Analysis

The PHA is intended to provide a qualitative analysis of the potential sources of hazards and failures in the VF and its support systems and mitigative features that would affect the potential consequences. It characterizes identified hazards associated with the VF in the context of both nominal process conditions as well as abnormal events including operator errors and equipment failures.

Accidents with a frequency of occurrence greater than 1E-06/year that result in significant radiation doses, or accidents with a frequency greater than 1E-04/year that result in exposures to high concentrations of toxic chemicals are identified as EBAs. The EBAs, as well as other accidents, are analyzed in Section C.9.4, *Radiological Accidents*, and Section C.9.5., *Nonradiological Accidents*. The EBAs represent bounding events with respect to the failure or error modes they involve; thus, they envelop all other accidents involving similar failure or error modes. For the specific purpose of comparing the predicted consequences of accidents with the

Evaluation Guidelines, no credit is taken for decontamination of airborne releases by HEPA filtration.

Summary results of the PHA are given in Tables C.9.3-1 through C.9.3-7. A rigorous failure modes and effects analysis has been performed for the vitrification process and is documented in Carrell 1987.

Hazardous chemicals were identified by comparing the normal site inventory with the material's Reportable Quantity (RQ) and/or Threshold Planning Quantity (TPQ). The RQ represents the amount of a material that must be released or spilled within a specified period of time before the party responsible for the discharge is required to report it to federal, state, and local governments. The TPQ is the amount of a material which requires various reporting, community right-to-know, and emergency planning requirements.

However, just because a material is present in excess of a RQ or TPQ, does not mean it is potentially releasable. The storage and use conditions and the release paths of each chemical were examined. Chemicals without a sufficient energy source or initiating event to release a significant quantity to the atmosphere for downwind dispersion were not included in the FSAR PHA. The nitric acid spill from Tank 65-D-05 met all the above conditions, and was reported in the PHA because it represented the bounding accident for chemical spills in the Cold Chemical Building.

Out of all the chemicals used or produced during vitrification, only nitrogen oxides (NO_x), nitric acid (HNO_3), and anhydrous ammonia (NH_3) had all three characteristics: (1) a significant quantity of material, (2) a viable initiating event and release path to the atmosphere, and (3) significant consequences to the on-site and/or off-site population.

Qualitative consequence (severity) classifications and probability (likelihood) classifications have been assigned to the accidents listed in these tables. The categories and their descriptions were adopted from DOE-STD-3009-94, July 1994. They are the following:

Qualitative Consequence Classification:

None — Negligible on-site and off-site impact on people or the environs.

Low — Minor on-site and negligible off-site impact on people or the environs.

Moderate — Considerable on-site impact on people or the environs; only minor off-site impact.

High — Considerable on-site and off-site impacts on people or the environs.

Qualitative Probability Classification:

	Annual Frequency	
Anticipated	>1E-02	Incidents that may occur during the lifetime of the facility.
Unlikely (U)	1E-02 to 1E-04	Accidents that are not anticipated to occur at some time during the lifetime of the facility
Extremely Unlikely (EU)	1E-04 to 1E-06	Accidents that will probably not occur during the life cycle of the facility.
Incredible (I)	≤1E-06	Accidents that are not credible.

C.9.4 Radiological Accidents

The radiological EBAs that are analyzed below in Sections C.9.4.1 through C.9.4.11 are summarized in Table C.9.4-1 as are the nonradiological accidents from Section C.9.5.

The larger quantities of radioactivity are present in the Vitrification Cell as the highly concentrated aqueous slurry, high-temperature molten glass, or solidified glass in stainless steel canisters. The aqueous slurry is the most easily dispersed high-level waste (HLW) form and, therefore, it becomes the predominant source term in all the potentially more serious events or hypothesized accidents. The combined, simultaneous release of HLW aqueous slurry and molten glass results in a large source term having a high energy content capable of dispersing the radioactive materials.

The key radioisotopes in the HLW to be processed in the VF have been developed and documented in several WVDP reports. The first major report, "High-Level Waste Characterization at West Valley" (Rykken-86) compiled and summarized both the isotopic distribution and the chemical composition data, based on the sampling and volume information available at that time from the two HLW tanks (8D-2 Purex and 8D-4 Thorex). Subsequently, this data was updated and resulted in the development of a complete process flow and mass balance for vitrification operations (Crocker-89). "Vitrification Mass Balance Revision Number 7" (Crocker-89), extended the scope of the "source term" report to include the planned combined stream compositions, glass formulation, and other process conditions. In addition, the radioisotope inventories were updated from new information and decayed to 1/1/90.

In 1995 the Crocker-89 document was revised to Rev. 8 (Nixon 95). This was done to reflect additional decay to 1/1/96 for some of the isotopes. It also recognizes certain process and glass formulation changes. The Crocker-89 mass balance has been used for the development of the accident analyses because it has all of the required dose contributing isotopes tabulated. However, any process conditions that bear on the accidents and have been modified in the new balance (Nixon 95), have been incorporated into the accident scenarios if the bounding conditions defined for a given scenario were exceeded. The use of the Crocker-89 balance, with isotopes being decayed to 1/1/90, adds a small additional degree of conservatism to the dose calculated.

The source terms used in the following accident analyses were developed conservatively in order to bound expected variations from the nominal values of process parameters. The most important of these parameters is that of the concentrated HLW slurry in the Concentrator Feed Make-up Tank (CFMT), which determines the hypothetical consequences of one of the relatively more severe accidents in the VF. Hence, for this analysis, a concentration well above the nominal value was assumed. (See Section C.9.4.1) Greater than anticipated variations from the nominal values of other process parameters would not result in significant increases in predicted accident consequences.

As noted above, no credit is taken for any HEPA filtration in comparing radiological TEDE to Evaluation Guidelines. However, in predicting accident consequences, a decontamination factor (DF) of 1,000 is assumed for the first HEPA filter in an effluent air stream, with an added DF of 100 assumed if there is a second filter in series with the first (Elder et al. January 1986). Therefore, two HEPAs in series provide a combined DF of 1E+05.

In the accidents analyzed in this Final Safety Analysis Report (FSAR), essentially all of the dose results from inhalation. For these dose calculations, a breathing rate of 20 L/min (5.3 gpm) was assumed. This is consistent with the recommendations in the International Commission on Radiological Protection (ICRP) "reference man" report, No. 23 1975, for an adult male engaged in "light activity." Because this is the predominant individual exposure pathway, the transuranic nuclides are the major contributors. Americium-241 is the single largest dose contributor and is responsible for approximately 60% of the dose from the Slurry-Fed Ceramic Melter (SFCM) off-gas stream and the spilled CFMT slurry mixture. Other isotopes that contribute greater than 1% of the TEDE from the CFMT slurry and the SFCM off-gas are listed in the tables summarizing the various accident analyses.

On-site and off-site dose predictions are a function of the assumed meteorological dispersion parameters. DOE-STD-1027-92 defines the distances and meteorological parameters to be used to calculate off-site and on-site doses to maximally exposed individuals from short-term releases. The DOE Standard discusses the adoption of the NRC-recommended (10 CFR 30) parameters (1 m/sec [2.2 mph] wind speed and Pasquill-Gifford Stability Class [PGSC] F) and a less conservative alternative for ground-level releases (4.5 m/sec [10.1 mph], PGSC D). In this FSAR, the more conservative values of 1 m/sec (2.2 mph), PGSC F have been assumed for all accident analyses involving ground-level releases. This approach results in calculated doses from ground level releases that are approximately twenty-four (24) times the doses that would be predicted by assuming a wind velocity of 4.5 m/sec (10.1 mph) and PGSC D.

For all accident analyses, a maximum exposure time of two hours at the site boundary is assumed. This assumption is justified by the fact that it would be possible to control (shut off) the source and/or remove any potentially exposed individuals within a two-hour period. The actual site boundary is easily accessible for surveillance or passes through rough, relatively inaccessible terrain where a person would be extremely unlikely to be loitering. In most cases, the duration of the release is less than two hours, so truncating the exposure is not an issue.

The site boundary χ/Q calculated by assuming these conservative parameters closely approximates the value used historically at the West Valley Demonstration Project (WVDP). The maximum two-hour χ/Q developed from site-specific meteorology for ground level releases and tabulated in *Radiological Parameters for Assessment of WVDP Activities* (WVDP-065) is 7.07 E-04 sec/m^3 (2.0E-05 sec/ft^3), only 13% higher than the value obtained by using the NRC- recommended 1 m/sec (2.2 mph) and PGSC F. This close agreement suggests that measured, five-year average meteorological parameters useful for probabilistic studies provide comparable results.

The χ/Q values used consistently for the radiological accident analyses described in this section are the following:

	OFF-SITE PUBLIC	ON-SITE CO-LOCATED WORKER
Distance from Ground Release	1,050 m (nearest boundary)	640 m (0.4 mile)
Wind Speed	1 m/sec	1 m/sec
Wind Stability	"F"	"F"
Relative Dispersion* χ/Q sec/m^3	6.23E-04	1.49E-03

* Calculated using EPICode 5.04.

For calculating the dose consequences of a radioactive release from the Main Plant stack (e.g., a process HEPA blow-out) at a nominal height of 60 m (197 ft), a relative dispersion factor of 6.72 E-05 sec/m^3 (1.9E-06 sec/ft^3) was assumed. This is the maximum site boundary value (at 1,700 m [1.06 mi] in the northeast sector) for a 0 to 2-hour release based on 95% meteorology as described in *Radiological Parameters for Assessment of WVDP Activities* (WVDP-065). The relative dispersion at the nearest site boundary (1,050 m [3,445 ft]) is approximately 60% of this value.

C.9.4.1 Concentrator Feed Make-up Tank Slurry Release

The CFMT receives HLW slurry from Tank 8D-2 and recycle slurry/solution from the Submerged Bed Scrubber (SBS). Approximately 20 m^3 (5,000 gal) of slurry, containing 4E+05 Ci, is concentrated in the CFMT by evaporation to approximately 4.3 m^3 (1,100 gal) and glass formers are added as a slurry, resulting in a volume of approximately 14 m^3 (3,800 gal). The evaporated steam passes through a demister to the Vessel Vent Header, is condensed in the Vent Condenser, and flows to a drain line that carries it to Tank 8D-3. The mixture in the CFMT is cooled and held for batch transfer to the Melter Feed Hold Tank (MFHT) when that vessel is ready to receive approximately 13 m^3 (3,500 gal) of slurry. Table C.9.4.1-1 summarizes the CFMT processing cycle including data on inventory, concentrations, and timing.

Approximately seven days are required to process one batch of slurry through the CFMT. However, concentrations and holding periods may vary depending upon melter feed rates. Nonetheless, the above values are typical, particularly the maximum concentration (a direct input to the release scenario) which, due to process considerations, could not be increased to any significant extent.

The dose consequences of slurry release accidents are concentration dependent. Therefore, for conservatism, a higher than anticipated maximum concentration, 58 percent solids as shown in Table C.9.4.1-1, was used as the basis for analysis of this specific accident. This concentration may be compared to the 49 percent solids content in the reference material/activity balance (Crocker October 10, 1989). The higher concentration will account for any non-uniform HLW slurry transfers from Tank 8D-2, or other deviations from the nominal values of process parameters. As discussed in Section C.9.4.11, *Nuclear Criticality*, concentration of the HLW slurry will not result in a credible threat of inadvertent criticality.

The escape of radioactivity is assumed to be initiated by a major rupture of the CFMT while its contents are at their maximum concentration. The entire contents of 4.3 m^3 (1,100 gal) is rapidly drained to the Vitrification Cell floor. (Note: This is the lower level floor at an elevation of 26.2 m [86 ft] with an area of 76 m^2 [816 ft^2]. See Figure C.5.2.7.1-5). If the CFMT actually were to rupture, there is a sump at the north edge of this area that would collect part of the spill, immediately setting off an alarm; however, it could collect only a small fraction of the released liquid because of its small size (it was designed to be a jet transfer collection point).

The release of approximately 4.3 m^3 (1,100 gal) would form a pool on the floor approximately 60 mm (2.4 in) in depth with a temperature of about 100°C (212°F). The slurry temperature would immediately start to drop because of conduction to the stainless steel/concrete floor as well as evaporative cooling. During the first ten minutes, these two mechanisms would cause cooling to occur at similar rates -- floor cooling at 1.0°C/min (1.8°F) and evaporation cooling at 1.1°C/min (1.9°F). After this initial period, although some additional cooling would result from heat conduction to the floor, the predominant mechanism would be evaporation. The temperature of the spilled material would be reduced to about 65°C (150°F) in one hour and would approach cell temperature, approximately 38°C (100°F), in six to eight hours.

The initial evaporation rate, when the slurry is at its maximum temperature and vapor pressure, is also the maximum rate of approximately 7 kg (15 lb) of water per minute. Neglecting any transient dilution by the volume of air present in the cell when the release begins, and considering only the dilution of the evaporating water by the cell ventilation rate of 4.0 m^3/sec (8,500 cfm) results in a concentration in the air of 28 grams of water per m^3 (1.8E-03 lb/ft^3). This concentration of water in air is equivalent to the dew point at 28°C (83°F). Hence, there will be no free water droplets impinging on the HEPA filters in the cell exhaust and their operational integrity will not be impaired. Water spray tests indicate that HEPAs will tolerate from 1.6E-02 to 3.2E-02 kg of free water per m^3 (1-2 lb per 1,000 ft^3 of air at nominal rated air flow rate) (Energy Research and Development Administration 76-21, *Nuclear Air Cleaning Handbook*). These data indicate that at the maximum evaporation rate above, even if the water were a mist (not a gas), the HEPAs would still operate satisfactorily.

Based on the above calculations, most of the thermal energy above 38°C (100°F) would be removed by evaporation of the spilled slurry. Even though some of the contained energy initially would be transferred to the floor, this energy eventually would be returned to the water and removed by evaporation. Therefore, the total energy removed would be 2.3E+05 kcal (9E+05 BTU). This would result in the evaporation of approximately 400 kg (900 lb) of water.

At its maximum concentration the HLW slurry contains 1.33E+02 Ci/kg water (Table C.9.4.1-1), equivalent to 60.3 Ci/lb water. The major radioactive isotopes which make up these curies are listed in Table C.9.4.1-2.

Two transport phenomena contribute to the release of radioactivity from the spilled aqueous slurry to the Vitrification Cell atmosphere. These are free fall splashing and evaporation from the liquid pool. The Airborne Release Fraction (ARF) values for these two physical phenomena are based on DOE-HDBK-3010-94 which, for a "splash" from the top of the CFMT at a height of 3 m (10 ft), lists a bounding ARF of 5E-05, and an ARF of 3E-05 for evaporation. When the ARF for evaporation of 400 kg (900 lb) of water is combined with the splash ARF, the fraction of the total inventory that becomes airborne is estimated to be 5.4E-05 for all nuclides except H-3. For tritium, the partition coefficient for boiling was assumed to be one (1).

Using this combined ARF, the curies that become airborne in the Vitrification Cell atmosphere were calculated and the resultant inventory was transported to the Vitrification Building stack (assumed to be at "ground level" although it is on the roof of the building). This airborne particulate radioactivity passes through double HEPA filtration which provides a total decontamination factor (DF) of 1E+05 (1,000 in the first, or in-cell filter and 100 in the second, or ex-cell filter; Elder, et al. January 1986). These calculations and the resultant doses are summarized by isotope in Table C.9.4.1-2. The calculated off-site dose is 0.07 mrem (7.0E-04 mSv) (based on the ground-level χ/Q of 6.23E-04 sec/m^3 [1.8E-05 sec/ft^3] at the site boundary, 1,050 m [3,445 ft] away), and the on-site dose is 0.2 mrem (2.0E-03 mSv) (χ/Q of 1.49E-03 sec/m3 [4.2E-05 sec/ft^3] at a distance of 640 m [2,100 ft]).

Other slurry release accidents could occur during different periods of the 7-day CFMT processing cycle. These would involve lower slurry concentrations and, therefore, lower predicted doses. Dose predictions for other batch cycle times would yield results similar to those quoted above because the maximum slurry concentration would remain the same. The batch cycle duration is critical to the analysis.

The above analysis assumes that the two stages of HEPA filtration in the Cell Ventilation system are operating normally with a combined DF of 1E+05. Without these filters, the resultant dose estimates would be 7 rem (0.07 Sv) off-site and 20 rem (0.2 Sv) on-site. These values are within the Evaluation Guidelines for this extremely unlikely event.

C.9.4.2 Loss of CFMT Vent Condenser Cooling

The vessel vent condenser, located in the vessel vent header, condenses steam/water vapor collected in the header. The principal vapor load on the condenser occurs during concentration of the HLW slurry in the CFMT. The evaporated water from the slurry carries with it a fraction of the radioactivity from the HLW. Transport of radioactivity via this path is reduced by the demister in the CFMT 410-mm (16-in) nozzle. Following condensation of the steam/water vapor, the non-condensible gas from the condenser flows to the process off-gas line, while the condensate is drained by gravity to Tank 8D-3.

If the vent condenser were to lose its cooling water supply, or if some other portion of the system or piping failed, the steam from the CFMT and the radioactivity carried by it could be released to the Vitrification Cell and to two other systems. This could be prevented, either by operator action in response to multiple alarms indicating the problem, or by automatic cut-off of the steam supply to the CFMT when the internal pressure of the CFMT rises above negative 12.7 mm (0.5 in) of water. Alarms would be activated by the vent header pressure build-up, condenser outlet temperature increase, and the rising CFMT pressure. Stopping the flow of non-radioactive steam which heats the contents of the CFMT would quickly reduce the rate of evaporation from the slurry. Not withstanding these likely mitigating actions, it is assumed for the purpose of evaluating this accident, that the non-radioactive steam flow to the CFMT continues after cooling water to the condenser has been lost.

There is no direct path out of the vent header to the environment, only three parallel paths through filtered systems. The distribution of radioactive steam from the CFMT through these different paths is described below. The analysis can be followed by reference to the simplified flow diagram in Figure C.9.4.2-1.

When cooling water to the vent condenser is lost, the condenser would continue to function for about five minutes because of the heat capacity of the water in the tubes and the tube metal. After that time, the uncondensed steam would increase the back pressure to greater than 508 mm (20 in) of water. This results in pressurizing the CFMT and the vent header. A fraction of the radioactive steam would continue to flow through the normal path from the condenser to the high efficiency mist eliminator (HEME) and through the Process Off-gas system to the Main Plant stack. In addition to the HEME, this path includes a HEPA filter in the Vitrification Cell, two stages of HEPA filters in the 01-14 building, the NO_x removal system, and extended lengths of connecting pipes and ducts.

A second potential path for flow of radioactive steam from the vent condenser is through the line which drains condensate to Tank 8D-3 during normal operation. However, because there is a 1,219-mm (48-in) water seal in this line below the condenser, this is not a credible route for steam flow.

There are two other possible paths for steam to flow to the 76-mm (3-in) waste header in the Vitrification Cell which then drains by gravity to Tank 8D-4. One of these connections is from the vessel vent header to the waste header via a 51-mm (2-in) line, but flow through this line is limited by a 12.7-mm (0.5-in) orifice. A second, more direct path with less resistance is from the CFMT, through the seal pot in a 76-mm (3-in) diameter overflow drain line, to the waste header. Although the seal pot has a 508-mm (20-in) water seal, the pressure produced by the steam build-up during this accident would be sufficient to blow out the seal.

Once the radioactive steam has reached the waste header, there are two possible paths for it to escape confinement. The more direct route is through the 76-mm (3-in) header to its connection to Tank 8D-4. Tank 8D-4 vents through 102-mm (4-in) and 76-mm (3-in) lines to HEPA filters and the Main Plant exhaust stack. A secondary path from the waste header is by backflow through the steam jet in the north sump into the Vitrification Cell and then out the cell HVAC exhaust system, passing through the primary, in-cell and secondary, ex-cell HEPA filters before discharge through the Vitrification Building stack. Along all of these lines, radioactivity would be deposited as the steam condensed; however, for conservatism in estimating doses, this removal mechanism was not considered.

The following parameters have been used to calculate the consequences of the loss of vent condenser cooling while continuing to heat the radioactive contents of the CFMT:

- Maximum slurry concentration of 133 total Ci/kg water (see Table C.9.4.1-1)

- Continuing boil-up rate of 450 kg/hr (1,000 lb/hr) This rate, approximately 50% greater than the nominal process design condition, is based on the maximum heat transfer capability at low volume, high slurry concentrations.

- A DF of 1,000 (partition coefficient of 1 E-03) for all nuclides except H-3 (DF of 1) in the boiling slurry within the CFMT. DOE-HDBK-3010-94 gives a bounding ARF for a boiling solution of 2E-03 which, based on the test procedure used to develop this value, is equivalent to a DF of greater than 1,000. As this bounding DF is based on a boiling solution, the value would be conservative for a boiling slurry, particularly with most of the major dose contributors in the solid phase.

- A DF of 10 for all nuclides except H-3 (DF of 1) in steam following the normal discharge path from the CFMT through the demister to the vent header (Larson December 1992)

- No fallout, plateout, or condensation assumed along the transfer lines, effluent ducts, in the vitrification cell, or Tank 8D-4

- The following HEPA filtration DFs for nuclides except H-3(DF of 1):
  - Process ventilation 1 E+05
  - HVAC cell ventilation 1 E+05
  - Tank 8D-4 ventilation 1 E+03

- Dose parameters for the important nuclides (rem at site boundary per curie released) based on DOE/EH-0070 & 0071 and χ/Q values given in Section C.9.4 above

In order to calculate the total off-site dose, it is necessary to estimate how the 450 kg/hr (1,000 lb/hr) of steam boil-up would be distributed among the three possible pathways described above. Once the flow of cooling water ceases and the steam is no longer condensed, the pressure drop across the condenser increases substantially and the 508-mm (20-in) water seal on the 76-mm (3-in) CFMT overflow line blows out, thus providing a direct connection to the 76-mm (3-in) waste header leading to Tank 8D-4. This HLW tank is ventilated through a 102-mm (4-in) line via a HEPA filter to the Main Plant stack.

After the CFMT seal pot is blown out, the steam flow would be distributed as follows:

- 236 kg/hr (520 lb/hr) through the demister (DF of 10). This flow is subsequently divided between two paths. 227 kg/hr (500 lb/hr) passes through the vent condenser, in-cell HEME and HEPA (DF of 1), two ex-cell HEPAs (DFs of 1,000 and 100), NO_x removal system (DF of 1), and out the elevated plant stack. The other 9 kg/hr (20 lb/hr) passes from the vent header through the restricting 12.7-mm (0.5-in) orifice into the waste header and ultimately through the open throat of the steam jet in the north sump along with an additional 45 kg/hr (100 lb/hr) which has reached the header via the blown seal pot as described below. This combined flow of 54 kg/hr (120 lb/hr) into the Vitrification Cell is discharged from the relatively short, "ground level" stack on top of the Vitrification Building.

- 172 kg/hr (380 lb/hr) through the blown seal pot and overflow line to the waste header, then to Tank 8D-4, through a single HEPA in the Waste Tank Farm area (DF of 1,000) and to the elevated plant stack for discharge.

- 45 kg/hr (100 lb/hr) through the blown seal pot to the waste header, then backflow through the header to the open throat of the steam jet in the north sump, where it joins the 9 kg/hr (20 lb/hr) which has reached this point via the 12.7-mm (0.5-in) orifice. As described above, this combined flow into the Vitrification Cell passes through the two HVAC HEPAs (DFs of 1,000 and 100) and out the "short" stack above the Vitrification Building.

All of these paths can be followed in the flow diagram, Figure C.9.4.2-1, which also shows the HEPA filter locations schematically. The steam distribution summarized above was calculated based on the flow resistance of the major components in each pathway. Balance is achieved when the CFMT is at a positive pressure of approximately 381 mm (15 in) of water.

With all HEPA filters in place, the maximum 2-hour dose at the site boundary from the radioactivity released through the Main Plant stack by this accident is 1.7 mrem (0.017 mSv). This is attributed to the 345 kg (760 lb) of steam from the waste header and Tank 8D-4; the contribution from the 454 kg (1,000 lb) which passes through the condenser and process vent is negligible. An additional 0.05 mrem (5.0E-04 mSv) would result from the 109 kg (240 lb) of steam which reaches the

Vitrification Cell and HVAC cell vent by backflow through the north sump jet pump and is discharged via the Vitrification Building stack. The on-site dose at 640 m (2,100 ft) from this source (assumed to be at ground level) would be 0.1 mrem (1.0E-03 mSv). The on-site dose from the Main Plant stack would be insignificant because of its approximately 60-m (197-ft) height.

The above results are based on the assumption that all HEPA filters are operating normally and providing a DF of 1E+03 or 1E+05 depending on the path taken by the steam. Without any of these filters, the resultant dose at any given location on the site boundary would be less than 6.7 rem (0.067 Sv) assuming that the CFMT continued boiling for two hours. (The 6.72 rem [0.0672 Sv] total shown in Table C.9.4.2-2 actually is the sum of the Main Plant stack dose maximum at 1,700 m [1.06 mi] NE and the dose at 1,050 m [3,445 ft] NW from the "ground level" Vitrification Building stack discharge.) The on-site dose at 640 m (2,100 ft) from the unfiltered discharges would be less than 12 rem (0.12 Sv) due entirely to the Vitrification Building stack effluent. These values are within the Evaluation Guidelines for this extremely unlikely event.

C.9.4.3 SFCM Off-Gas Jumper Failure

The HLW slurry is pumped from the MFHT to the SFCM, where it is formed into molten glass. The glass then flows from the SFCM via an airlift overflow spout into a stainless steel canister. The maximum hypothetical radioactivity release from the glass melting step would result from the discharge of melter off-gas directly into the Vitrification Cell following a catastrophic jumper failure. This might conceivably occur as a result of a DBE. The off-gas jumper is constructed of 150-mm (6-in) diameter Inconel pipe. Corrosion could cause this jumper to fail, but such a failure would be more gradual and would not result in a sudden release at a high rate as assumed in this accident. Failures could range from small leaks (e.g., if the jumper were incorrectly connected to the SFCM or SBS) to a complete rupture. A small leak would cause no release of activity to the cell because air would flow into the jumper from the cell as a result of the negative pressure maintained in the melter by the Process Off-gas system, rather than into the cell.

The off-gas jumper runs from the SFCM to the Submerged Bed Scrubber (SBS). To maximize the consequences of this accident scenario, it was assumed that the failure occurs when slurry feed is being pumped into the SFCM, and that the feed continues unabated for two (2) hours following jumper failure. Several alarms, (pressure and temperature) as well as observation of "steam" in the Vitrification Cell, probably would alert the operator to this failure. After a time much less than the assumed two hours of full feed, the supply of slurry very likely would be shut-off by the operator and the off-gas rate would decrease rapidly and continue to decrease for several hours. It might, at a later time, increase somewhat as discussed below.

Although a complete failure or major break in the off-gas jumper connection with feed continuing unabated for two hours has been assumed in this scenario, this is not likely to occur. The relatively short, two to three year period of vitrification operations, minimizes the likelihood of fatigue failure of the jumper material or its connections. Any substantial failure of the jumper would greatly alter the pressure profile in the Process Off-gas system and set off alarms that would alert the operators to abnormal conditions. In addition, steam leaking from a failed jumper into the cell would be observed by the operators. If this occurred, the feed would immediately be stopped by the operators and the SFCM would be placed in idle/stand-by condition. Thereupon, off-gas production would decrease rapidly.

Based on measured off-gas production rates (Total Source Analysis, Inc. October 3/November 21, 1989), the following release rates would be predicted if an operator intervened after thirty minutes:

- 0-0.5 hours - normal release rate (feed continues from 0-0.5 hrs, and is stopped at 0.5 hrs by operator action).
- 0.5-2.5 hours - 27% of normal release.
- 2.5-5.5 hours - 14% of normal release.

These assumptions are based on the melter remaining at its nominal operating temperature. Therefore, because volatility is temperature-dependent, the release rate is over-estimated. Releases to the Vitrification Cell from the three-step scenario described above are equivalent to that which would occur during 1.46 hours of normal operation. However, as noted above, a conservative, two-hour release with no operator action was assumed as the basis for analyzing this accident. The quantity of radioactivity released to the cell during this two-hour period was calculated from the total off-gas discharge of each nuclide given in the Crocker October 10, 1989 mass balance for the entire glass-making campaign and the assumption that the total production run time would be 13,800 hours.

After a long period of time (i.e., greater than 6 hours), if the SFCM heaters were not turned off, there may be some increase in off-gas flow. This apparently is from "feed material" on the roof of the melter cavity achieving a higher temperature and melting/dropping onto the glass surface. Rounding the equivalent integrated time of release up from 1.46 hours to 2 hours, as assumed above, would compensate for this longer term effect, even if the heaters were not turned off.

Table C.9.4.3-1 lists the curies of radioactivity released into the Vitrification Cell and the calculated on- and off-site EDEs from the isotopes that contribute more than 1% to the total doses. No removal (fallout/plate-out) of the particulate radioactivity in the Vitrification Cell is assumed. However, prior to discharge, the two stages of HEPA filtration in the Vitrification Cell Ventilation system reduce the concentration of airborne activity by a factor of 1E+05 (1E+03 DF for the first stage plus a DF of 1E+02 for the second stage). The release, which is from a relatively short stack on the roof of the Vitrification Building, is considered a ground-level discharge for the purpose of calculating the dose consequences.

The resultant TEDE from the two-hour release is 0.05 mrem (5.0E-04 mSv) to the maximally exposed individual off-site (χ/Q of 6.23E-04 sec/m^3 [1.8E-05 sec/ft^3]), and 0.11 mrem (1.1E-03 mSv) to the on-site worker (χ/Q of 1.49E-03 sec/m^3 [4.2E-05 sec/ft^3]).

Other, less significant releases are possible from the SFCM. If the negative pressure in the SFCM rises, the valve in the 150 mm (6 in) line to the process vent header will open. Normally, the flow would then go through the Vent Condenser to the HEME, out through the in-cell filters, the two stage ex-cell HEPA filters and the NO_x removal equipment. If this path were not operable, there would be flow from the SFCM to the cell (leakage paths) and backflow to the waste header which could leak to the Vitrification Cell (backflow through the north sump jet) or to the 8D-4 tank and its HEPA filtered ventilation system. Another possible path is through the condensate drain system to Tank 8D-3, which also is a HEPA filtered path. All of these paths lead to contained systems. The most probable path is into the Vitrification Cell. Hence, the jumper failure accident above bounds these alternative pathways.

The above analysis assumes that the two stage HEPA filters of the Cell Ventilation system are operating normally with a combined DF of 1E+05. Without these filters, the resultant dose would be 5 rem (0.05 Sv) off-site and 11 rem (0.11 Sv) on-site, values which meet the Evaluation Guidelines for this unlikely event.

C.9.4.4 Molten Glass Spill from the SFCM

The maximum molten glass spill accident would involve a rupture of the SFCM and loss of the entire melter contents to the floor of the Vitrification Cell. Other molten glass spills could occur in the turntable due to overfilling or improper positioning of a canister to receive the molten glass.

A spill from the SFCM would result in alarms similar to those enumerated above in Section C.9.4.3 which would alert the operators to shut down the system, including feed to the SFCM.

In the accident involving rupture of the SFCM, the entire melter inventory (approximately 0.86 m^3 [30.4 ft^3], corresponding to approximately 2,060 kg [4,500 lb]) is assumed to be dumped on the cell floor. This scenario is somewhat analogous to the off-gas jumper failure analyzed in Section C.9.4.3 above, although the path by which radioactivity from the molten glass escapes to the Vitrification Cell is different. However, spillage of glass to the floor would result in a significantly lower radioactive release, based on a comparison of the conditions which would affect the rate of release during three stages:

- In the first stage, the period of continued slurry feed, significant release could occur, as indicated in Section C.9.4.3. However, because of the obvious and catastrophic failure mechanism, it is probable that the slurry feed would be stopped quickly by operator action.

- In the second stage (0.5-2.5 hrs) and third stage (2.5-5.5 hrs), since release rates are temperature-dependent, and since the cool-down rate would be very rapid for the pooled glass on the floor (a 51-mm [2-in] deep pool, 4.6 m [15 ft] across), releases would be much less than during the corresponding stages following an off-gas jumper failure. In the latter case, the molten glass would remain insulated in the SFCM and, therefore, would continue with a higher temperature providing the principal driving force for release to the cell atmosphere.

Regardless of the detailed sequence of events and the possibility of operator intervention, it is estimated that the maximum total release would be from 10% to 30% of the release from the off-gas jumper failure. Calculation of the dose consequences of an off-gas jumper failure was based on the assumption that there was no human intervention to mitigate or terminate the accident. Therefore, the dose from a molten glass spill, followed by no operator action, may be estimated conservatively and simply by taking 30% of the corresponding EDE values listed in Table C.9.4.3-1 for the off-gas jumper failure accident. The resulting dose estimates are 0.01 mrem (1.0E-04 mSv) to the maximally exposed off-site individual and 0.04 mrem (4.0E-04 mSv) at a distance of 640 m (2,100 ft) on-site. This analysis assumes that the two stage HEPA filters of the Cell Ventilation system are operating normally with a DF of 1E+05. Without these filters, the resultant doses would be 1.4 rem (0.014 Sv) off-site and 4 rem (0.04 Sv) on-site, values which meet the Evaluation Guidelines for this extremely unlikely event.

C.9.4.5 Steam Explosion in the SFCM

In a glass-forming process in which an aqueous slurry is mixed with high-temperature molten glass, there is concern about the possibility of a steam explosion and resultant over-pressurization of the SFCM. Such a series of events was considered at the outset of the WVDP and results of a careful study of this possibility were reported in two documents (Hutcherson et al. December 1984 and Hutcherson and Henry February 5, 1985). The conclusions of these two reports are summarized in what follows in this section.

Vapor explosions are generally limited to liquid-liquid systems in which a hot, non-volatile liquid (such as molten salt) is brought into contact with a colder, volatile liquid (such as water). A necessary factor for propagation of an explosion is the rapid development of a large interfacial area (usually referred to as fragmentation and intermixing) between the two materials. This is necessary to obtain significant energy transfer in a sufficiently short time to produce an explosion. If the vaporization is rapid enough to produce shock waves, the phenomenon is generally termed a vapor explosion.

The analyses referred to above showed that the explosive potential from mixing water and molten glass is limited, because of high glass density, viscosity, and negligible mixing velocity, to about 0.1 kg (0.22 lb) of water for the SFCM conditions. In considering the maximum possible interaction, it should be noted that the "water" feed rate to the melter is low (less than 1 kg [2.2 lb] of water/min), and that even in the absence of a cold cap in the melter, the water is insulated from the glass by its own vapor film. There is no mechanism that can be hypothesized to cause significant mixing/penetration of the water feed into the glass, a requirement for initiation of a steam explosion. The cold cap present in the normal operations further mitigates against mixing.

A detailed stress analysis performed on the melter vessel showed the vessel capable of accommodating an energetic steam explosion well in excess of that involving 0.1 kg (0.22 lb) of water. From calculations based on the maximum, experimentally observed efficiency for steam explosions, it has been shown that the SFCM is capable of accommodating a steam explosion involving vaporization of about 5 kg (11 lb) of water without failing (Hutcherson et al December 1984). The probability of a steam explosion of this magnitude is considered to be extremely unlikely for the SFCM configuration and conditions. Steam explosions have a relatively slow time frame which does not produce significant shock waves, so that no other equipment in the Vitrification Cell would be damaged by this hypothesized event. Further, the evaporation of 5 kg (11 lb) of water would produce only 9 m^3 (300 ft^3) of steam which, in the Vitrification Cell volume of 2,600 m^3 (92,000 ft^3), would have little effect.

A different route for water to contact molten glass would be created by a failure of the water cooling jacket. In order for this water, which is at 100 kPag (15 psig), to reach the molten glass it would have to pass through the boundaries of the insulating refractory blocks (Monofrax [R] K-3), which are multi-layered and 400 mm to 700 mm (15.7 in to 27.6 in) thick. As the water progresses through this boundary matrix in which the temperature is rapidly rising, it volatilizes to steam. The back-pressure of the steam soon would be greater than the water pressure, which would prevent further transport of liquid water into the glass. The pressure developed by this steam could rupture the water jacket and thus cause the melter to fail. The consequences of this event are bounded by the results of the total SFCM inventory spill analyzed above in Section C.9.4.4. It should also be noted that this same water jacket, and the cooler refractory blocks near it, would be a mitigating feature to eliminate or, at a minimum, reduce the consequences of the loss of the entire SFCM contents.

In summary, if a steam explosion were to occur, the consequences would be loss of glass confinement in the SFCM. Because the pressure rise is relatively slow (as compared to a chemical explosion), a major shock wave would not be produced and damage to other components in the Vitrification Cell, particularly the HEPA filters, would not occur. The result of the spill would be similar to that of the SFCM rupture analyzed in Section C.9.4.4, and would result in a similar dose of 0.01 mrem (1.0E-04 mSv) to the maximum off-site exposed individual and 0.04 mrem (4.0E-04 mSv) to the on-site worker. If HLW slurry feed continued after the explosion, as in the off-gas jumper failure scenario (Section C.9.4.3), the resulting doses would be 0.05 mrem (5.0E-04 mSv) off-site and 0.13 mrem (1.3E-03 mSv) on-site. The above analysis assumes that the two stage HEPA filters of the Cell Ventilation system are operating normally with a DF of 1E+05. Without these filters, the resultant doses would be 5 rem (0.05 Sv) off-site and 13 rem (0.13 Sv) on-site, values which meet the Evaluation Guidelines for this extremely unlikely event.

C.9.4.6 HLW Canister Drop

After the stainless steel canisters are filled with approximately 1,900 kg (4,200 lb) of glass per canister, they are allowed to cool on the canister turntable until the centerline temperature is below the nominal solidification temperature of 550°C (1,000°F). They are then lifted by crane from the turntable, moved to the canister capping station and then to the decontamination station. Next, they again are lifted by crane and placed on a cart with a capacity of four canisters for transfer to HLW Interim Storage (HLWIS) for on-site storage until they are shipped to a repository.

There are two primary ways in which a canister could be ruptured: a canister could be dropped during a transfer operation; or a heavy object could be dropped on a canister. Neither accident would be likely to breach a canister, which must occur for there to be even a small release of radioactivity. The canister material is tough with rather high ductility 304L stainless steel with a 3.4 mm (0.135 in) wall thickness. The canisters are designed to resist breaching and tested to withstand a 7-m (23-ft) drop to an unyielding surface. A 7-m (23-ft) drop is equivalent to an energy deposition in the glass canister of 0.18 joules/cm^3. Moreover, heavy objects (other than the canisters themselves) are not routinely located or moved above canisters in the Vitrification Cell or elsewhere. Therefore, the dropping of a heavy object on a canister is not probable. All crane operations will be done remotely with visual monitoring and in compliance with WVDP-082, the DOE *Hoisting and Rigging Manual*.

There is only one location in the Vitrification Cell from which a maximum drop of approximately 10 m (32.8 ft) is possible. Specifically, this could occur when a canister is suspended by the crane over the north pit area of the Vitrification Cell while being moved from the turntable to the interim storage rack. At this location, the maximum possible lift height, above that required for a normal transfer, is slightly less than 10 m (32.8 ft). This location is not on the normal transfer path so that a move to this area could not occur unless there were an operator error. Further, the latch design is such that failure probabilities are minimal. In addition, there is a reasonable probability that a 10-m (32.8-ft) drop would not rupture the canister. Not withstanding these mitigating circumstances, it is assumed that a drop occurs in this high lift area with consequences that are analyzed below.

The fragmentation (pulverization) of brittle materials has been investigated by Argonne National Laboratory (Jardine et al. 1982) with results that are presented as ARFs and summarized in DOE-HDBK-3010-94. ARFs have been correlated to drop height and/or energy developed by a drop. For a 10-m (32.8-ft) drop of bare (i.e., unencased) pyrex glass (equivalent to HLW glass), the ARF (particles <10 μm [<3.9E-04 in] in diameter) is 5.2E-05, and the energy developed is 0.27 joules/cm^3. In a canister rupture, most of the fines (<10 μm [<3.9E-04 in]) would be contained by the stainless steel canister walls. Moreover, a smaller fraction of fines would be generated because of the "cushioning" effect of the canister walls, and the release would also be limited by the small size of the canister cracks (i.e., only a small fraction of the fines would be located adjacent to a crack, and thus be able to escape from the canister). An ARF of 10% of that which would occur for bare (unencased) glass has been assumed for this analysis (i.e., 5.2E-06).

The resultant airborne release to the Vitrification Cell is 0.56 Ci. These data are summarized in Table C.9.4.6-1. After two-stage HEPA filtration, the resultant TEDE is predicted to be 2.0E-03 mrem (2.0E-05 mSv) off-site, and 5.0E-03 mrem (5.0E-05 mSv) to the on-site worker at 640 m (2,100 ft). The above analysis assumes that the HEPA filters of the Cell Ventilation system are operating normally with a DF of 1E+05. Without these filters, the resultant doses would be 0.2 rem (2.0E-03 Sv) off-site (based on the ground-level χ/Q of 6.23E-04 sec/m^3 [1.8E-05 sec/ft^3] at the site boundary, 1,050 m [3,445 ft] away) and 0.5 rem (5.0E-03 Sv) on-site (χ/Q of 1.49E-03 sec/m^3 [4.2E-05 sec/ft^3] at a distance of 640 m [2,100 ft]), values which meet the Evaluation Guidelines for this unlikely event.

It is possible that a drop could occur prior to the capping operation. However, little energy would be imparted to the open, upper end of the canister by the drop. Hence, negligible fines (<10 microns [<3.9E-04 in]) would be produced at this opening. Therefore, the bottom impact scenario developed above would be the bounding drop event.

C.9.4.7 Blow-out of Vitrification Cell HEPA Filters

There are two routes for gas to flow out of the Vitrification Cell, both of which are through multiple HEPA filters. The Process Off-gas system removes particulates in the off-gas resulting from the SFCM vitrification step. The HVAC cell ventilation system HEPA filters the ambient Vitrification Cell atmosphere prior to its discharge to the outside. These effluent exhaust systems have different source terms, filter loadings, and discharge points. Therefore, the hypothesized blow-out accidents are analyzed separately. In both analyses, it is assumed that blow-out occurs when the filters are at their maximum loading.

C.9.4.7.1 Process HEPA Blow-Out

The in-cell process HEPA filters receive the SFCM off-gas after it has passed through the SBS and the HEME. There are two parallel sets of filters within the cell that are used alternately, so only two filters in series are active at any time. It is assumed that all of the radioactivity removed from the off-gas stream is captured by the first of the two series filters and, therefore, the accident source term is from only one HEPA filter. Beyond the Vitrification Cell, i.e. ex-cell, the process gas flows through two additional stages of HEPA filtration, NO_x catalytic bed removal equipment and then to the 60-m (197-ft) Main Plant stack for release. The in-cell process off-gas HEPA filter assembly is tested for HEPA level efficiency prior to installation. The assembly cannot be aerosol tested after installation. However, since it is a "stand alone" assembly, there is nearly no chance of losing HEPA level efficiency after installation due to mis-seating of the filters within a housing structure. As a result, the two sets of in-cell HEPA filters are assumed to have a DF of unity when releases from normal melter operation are being estimated. However, these in-cell HEPA filters are designed to standard specifications so that they are expected to collect essentially all particulates greater than 0.3 microns (1.2E-05 in) in size.

It is assumed for the purpose of defining a bounding accident that the in-cell process HEPAs will not be changed-out and that all particulate activity from the vitrification campaign will be collected on a single filter. The total curies collected on this filter is determined by the DF in the several process steps prior to the filter; namely, the process steps provided by the SFCM, the SBS, and the HEME. DF values have been defined for these pieces of equipment in Attachment D of Nixon 95, and based on those factors the curie balance was calculated. Not all of the key isotopes are included in Nixon 95, so the removal efficiencies in that document have been used to modify the isotopic distribution ratios from Crocker-89. These filter loadings for the total vitrification campaign are tabulated as the source term in Table C.9.4.7.1-1. The back-up filters, ex-cell, would also have the potential for a blow-out but the radiological release would not approach that of the in-cell filters.

It is a characteristic of HEPA filters that the particles removed from the air stream become imbedded deep in the filter matrix. Therefore, in a blow-out, only a small fraction of the inventory would be dispersible over an extended distance. Also, only a fraction of the entire filter media would escape. Both of these factors reduce the total release of radioactivity in a blow-out accident, and have been considered in estimating the fraction of the filter loading that contributes to the airborne release. The total release fraction from a filter blow-out recommended in DOE-HDBK-3010-94 for application to accident analyses is 1% of the total filter loading, with all of the released activity considered to be fully respirable.

Data which summarize the analysis of this accident are presented in Table C.9.4.7.1-1. Because in this accident the radioactivity would escape from the elevated Main Plant stack, the maximum 0 to 2-hour χ/Q of 6.72 E-05 sec/m^3 (1.9E-06 sec/ft^3) from WVDP-065 was used as the basis for the dose estimates. As described above in Section C.9.4, this value is based on 95% probability parameters measured at the West Valley site. In this case, the maximally exposed off-site individual is located 1,700 m (1.06 mi) northeast of the stack. The EDE at the nearest boundary (1,050 m [3,445 ft] NW) from an elevated release would be approximately 60% of the dose at 1,700 m (1.06 mi) NE. Because of the nominal 60-m (197-ft) stack height, use of this χ/Q value results in a higher calculated dose than using the 1 m/sec (2.2 mph), PGSC F parameters which are assumed for ground level releases elsewhere in this FSAR. It should be noted with regard to this analysis that the extremely conservative assumption is made that the two ex-cell stages of HEPA filtration following the in-cell filters also fail, although the probability for sequential failure is extremely low. In addition, no credit is taken for any air cleaning capability of the NO_x catalytic bed removal equipment.

The calculated dose is 200 mrem (2.0 mSv) to the maximally exposed individual off-site. On-site doses are negligible for such elevated stack releases. These EDE's are a small fraction of the Evaluation Guidelines for this unlikely event.

C.9.4.7.2 HVAC HEPA Blow-Out

The HVAC components that service the Vitrification Cell normally operate with two of the three parallel, in-cell HEPA filters on line so that it can be hypothesized that two fully loaded filters blow-out simultaneously. The isotopic filter loading summarized in Table C.9.4.7.2-1 represents the total curies loaded onto two filters, each producing an exposure rate of 10 R/hr at a distance of 0.3 m (1.0 ft).

A source term loading equivalent to 10 R/hr is greater than the anticipated loadings. Airborne radioactivity in the Vitrification Cell primarily will result from two sources: liquid slurry spills; and SFCM off-gas releases that may occur during the vitrification campaign. To estimate the activity that becomes airborne from slurry spills, it was assumed that 0.1% of the total slurry throughput is released and that the nuclides then escape to the cell atmosphere with a partition coefficient of 1E-03. In addition, a 1E-05 fraction of the SFCM off-gas also escapes. These two sources would produce a total HEPA loading of 8.8 Ci of Cs-137 (4.4 Ci per filter) and an exposure rate from each of the in-cell filters of 5 R/hr at 0.3 m (1.0 ft), half of the value assumed for this accident. Hence, filter change-outs based on external radiation level are not anticipated during the vitrification campaign.

After leaving the Vitrification Cell, the ventilation air passes through a second stage of HEPA filtration (i.e., secondary filter unit 67-T-002A), and is then discharged from the relatively short stack on the roof of the Vitrification Building (considered a "ground-level" release). A conservative 1 m/sec (2.2 mph) wind speed and PGSC F were assumed for the dispersion calculation, resulting in a χ/Q value of 6.23 E-04 sec/m^3 (1.8E-05 sec/ft^3) at the site boundary 1,050 m (3,445 ft) to the northwest. As in the analysis of the process HEPA blow-out above, 1% of the filter loadings were assumed to be released without subsequent filtration by the downstream, unit 67-T-002A HEPA filters.

The resultant dose from an HVAC in-cell HEPA filter failure to the off-site maximally exposed individual is 230 mrem (2.3 mSv), and 550 mrem (5.5 mSv) to the on-site worker at 640 m (2,100 ft) distance. These values meet the Evaluation Guidelines for this unlikely event.

In analyzing both the Process Off-gas system and the HVAC Cell Ventilation system, it is difficult to hypothesize a credible scenario in which multiple, sequential HEPA filter blow-outs would occur. It is only if the entire train of series HEPA filters failed that the significant, though still relatively small doses would occur as projected herein.

C.9.4.8 Loss of Vitrification Cell Coolers

There are four Vitrification Cell coolers. Each is designed to remove approximately 176,000 kcal/hr (700,000 BTU/hr), which is in excess of the nominal heat load released to the cell air from the SFCM, process tanks, lighting, motors, etc. Therefore, only one of the units is required and is normally in operation. Because of this redundancy, loss of all cell cooling capacity would require a common cause such as loss of cooling water or power to all units. These failure scenarios would not impair cell ventilation, which has diesel back-up for the normal and back-up blower power supplies. Hence, the normal cell ventilation flow of 240 m^3/min (8,500 ft^3/min) would continue if cell cooling were lost.

The Vitrification Cell has an air volume of 2,600 m^3 (92,000 ft^3). Upon cooler failure, a 176,000 kcal/hr (700,000 BTU/hr) maximum theoretical load would heat up this volume initially at a rate of 4°C/min (7°F/min). This rate would decrease as the cell air became hotter because of the reduced temperature differential between the air and the heat source (cell vessels), and also because of increased heat transfer from the cell air to cooler surfaces in the cell. At the initial (and maximum) heating rate, the cell air expansion would be approximately 37 m^3/min (1,300 ft^3/min). With the Vitrification Cell ventilation system operating at 240 m^3 (8,500 ft^3/min), negative pressure would be maintained and there would be no unfiltered out-leakage from the cell.

Considering only the heat removal capacity of the ventilation air, 240 m^3/min (8,500 ft^3/min), and neglecting any heat removal by the cell walls, etc., the temperature rise would be approximately 42°C (76°F). The maximum temperature would be 66°C (151°F) (vent air in at 24°C [75°F] and out at 66°C [151°F]). When the heat sink characteristics of the cell are considered, the maximum temperature would be substantially less, e.g., 51.7°C to 60.0°C (125°F to 140°F), and would take several hours to reach.

Multiple failure scenarios involving the cooler system and the Cell Ventilation system are developed in Section C.9.4.9 and bound this analysis.

C.9.4.9 Loss of Vitrification Facility Power

The key systems that assure Vitrification Cell confinement are the Cell Ventilation system, and the cell coolers which would mitigate the release of radioactivity if cell ventilation were to fail. The consequence of cooler loss alone was developed in Section C.9.4.8. Because the Cell Ventilation system was assumed to continue in operation, the loss of the coolers resulted in only a temperature rise and no release consequences.

A complete loss of power, including the back-up power supplies to the Process Off-gas and Cell Ventilation systems, would require multiple failures and is unlikely. Notwithstanding the back-up redundancy, the consequences of simultaneous process and cell ventilation failures due to complete loss of power have been calculated. The Process Off-gas system has back-up power provided by two standby diesels. If this system stopped operating, the SFCM off-gas leakage to the cell at the maximum rate would be similar to the leakage rate following the SFCM jumper failure (see Section C.9.4.3).

A fraction of the radioactivity that leaked into the cell from process vessels would leak out of the cell because of the pressure rise as the cell air heats up. (With a total loss of power, the cell coolers could not operate.) The total out-leakage from the Vitrification Cell is a function of the temperature rise in the cell. As described in Section C.9.4.8, the initial rate of temperature rise is 4°C/min (7°F/min), with the rate decreasing with time as a result of the smaller temperature differential between the hot process vessel surfaces and the air and the increased heat transfer from the hot air to cooler surfaces. With no ventilation, heat transfer from the cell air to cooler surfaces would be the only "removal" mechanism.

Calculations of the rate of heat transfer to the cell air indicate that in a 1-hour period, the initial 176,000 kcal/hr (700,000 BTU/hr) transfer rate to cell air would be reduced by both the cell air temperature increase and the source temperature reduction to less than 76,000 kcal/hr (300,000 BTU/hr). With regard to heat removal, using a conservative (low) heat transfer rate to cell walls and "cold" equipment, it was estimated that an air/wall temperature difference of 28°C (50°F) would result in the transfer of on the order of 76,000 kcal/hr (300,000 BTU/hr). Hence, the temperature would rise to less than 66°C (150°F). An increase in temperature of 33°C (60°F) would result in a volume increase of 11% resulting in an escape from the cell due to expansion of approximately 300 m^3 (11,000 ft^3). Most of this cell out-flow (73%), following the path of least resistance, would be backflow through the inlet HEPA filters (through the Crane Maintenance Room and Transfer Tunnel). The balance (27%) would escape to the Vitrification Building galleries. For purposes of this analysis, this fraction is assumed to be released at ground level.

Combining the fraction release to the cell with the "unfiltered" leakage from the cell results in a total leakage to the environment of a volume equivalent to 3% of the SFCM off-gas for 1 hour. These data and the conversion of curies to on-site and off-site dose are summarized in Table C.9.4.9-1. The resultant dose is 28 mrem (0.28 mSv) to the maximally exposed off-site individual, and 66 mrem (0.66 mSv) to the on-site worker. These EDEs are well within the Evaluation Guidelines. The probability of occurrence for a total loss of power to the VF is estimated to be in the unlikely category.

C.9.4.10 Design Basis Tornado

The Vitrification Cell confinement structures (i.e., cell walls, roof, doors, and the Cell Ventilation system) are designed to withstand the forces of a Design Basis Tornado (DBT) having an annual return frequency of 1E-06. Although the basic cell structures and Ventilation system would continue to function as required during and after passage of a DBT, the tornado could, in theory, generate a missile capable of penetrating the shield windows which extend through the cell wall, thus jeopardizing the confinement integrity. The shield windows measure approximately 580 mm high x 1,070 mm wide x 1,200 mm thick (23 x 42 x 48 in) and are constructed of multiple glass layers and filled with mineral oil (Sontex 100 LT).

The possibility of a tornado missile breaking the shield window was analyzed during the Vitrification Cell design (Kupp August 23, 1989). This analysis demonstrated that even if a tornado missile did penetrate a shield window, integrity of the cell confinement would be maintained except for a few cubic feet of cell atmosphere that would escape during the 4.5 seconds required for the tornado eye to pass by. This total leakage would be equivalent to the release of radioactivity through the two-stage HEPA filters during two days of normal operation, and hence is negligible. This question was revisited by the NRC in a study by Pomerening 1993, which is based on new empirical test data. This study concluded that the shield window will not fail from impact of the DBT missile.

The probability of the shield window being penetrated was not quantified in the prior analyses except for the basic categorization of the DBT as a 1E-06 per year event. However, there are mitigating factors that would further reduce the probability of window penetration by a missile. Quantification of some of these mitigating effects follows.

Considering the dynamics and geometry of a tornado, a missile of maximum velocity would be generated toward the perimeter of the tornado where the wind velocity would approach 72 m/sec (160 mph). Although the preceding winds, which would be greater than 22 m/sec (50 mph), could cause some damage, major destruction is typically from the outward "explosion" of a building when the low-pressure eye passes over it, or alternately when the maximum wind velocity vector strikes the building. Thus, it is probable that a tornado missile would first strike the outer shell of the Vitrification Building (still intact) which would absorb much of the missile's energy before it could hit the shield wall or window of the Vitrification Cell. Also, the flight path of the missile would be impeded by structural steel, piping, instrument racks, and other equipment located in the operating gallery at the 33.5 m (110 ft) elevation. Although it is impossible to rigorously assign a probability to the loss of energy from the missile first encountering other objects in the Vitrification Building, a plausible reduction of the missile force would result in only 10% of the missiles reaching the cell confinement wall with full force.

A second geometrical consideration is the relative target area represented by the shield windows at risk. There are six windows in the Vitrification Cell, representing 0.5% of the total wall area. If ten design basis missiles struck the wall, the probability of one of them actually hitting a window would be only 5%. Moreover, for a missile to have the maximum possibility of penetrating a window, its total energy must be at the point of impact and at right angles to the struck surface. In order to penetrate a window, a pipe-type missile must strike perpendicularly or at close to a right angle to compensate for any rotational energy it normally would have as a result of the acceleration process. The development of maximum missile velocity assumes that the largest projected area of a missile remains normal to the tornado wind without tumbling (i.e., at right angles to the wind, rather than oriented axially). The probability of a missile striking at the maximum effective rotational position is not large. A 10% probability has been assumed for this analysis.

Applying the above factors to estimating the probability that a missile generated by the DBT (with an annual return frequency of 1E-06) would penetrate a shield window results in an incredible event. Specifically, the frequency of a missile striking the window with sufficient force to cause penetration is 5E-10 per year.

C.9.4.11 Inadvertent Nuclear Criticality

The HLW in Tank 8D-2 which serves as the feed to the vitrification process is comprised of solids suspended in a liquid to form a slurry. The form and composition of this liquid feed material are fully described in Chapter 6. Uranium and plutonium in this HLW exist as insoluble salts. Plutonium is also associated with the waste zeolite generated during sludge mobilization and washing. The slurry in Tank 8D-2 (consisting of the PUREX sludge, THOREX, and zeolite) is well mixed prior to transfer by use of mobilization pumps installed in the tank. The slurry is subsequently pumped to the CFMT in the Vitrification Cell where it is concentrated by evaporation. CFMT concentrates are maintained in a well mixed condition through the use of a mechanical agitator (Carl et al. September 30, 1990). Following concentration, samples of the waste are collected and analyzed to determine the amount of glass formers and process chemicals necessary to produce a qualifiable waste form. This prepared waste is pumped to the MFHT to serve as feed to the SFCM. A mechanical agitator maintains the slurry in a well mixed condition in the MFHT.

Feed pumped to the SFCM is contained within a refractory having sloped walls and a flat bottom. Glass in the melter cavity is heated to a temperature between 1150-1200°C (2,100 - 2,200°F) with mixing achieved by heat-induced convection currents. The molten glass is poured from the melter into a HLW canister for storage. A comprehensive description of the vitrification process is given in Section C.6.3.

The chemical form of uranium in the feed stream received in the CFMT and in the MFHT is uranium dioxide (UO_2) or uranium hydroxide ($UO_2[OH]_2$). Because of the elevated temperature in the SFCM, uranium hydroxide is reduced to uranium dioxide and remains in this form following vitrification. Plutonium, which exists as plutonium dioxide (PuO_2) in the waste feed, remains in this form throughout the vitrification process. The relative isotopic abundances of U and Pu in the vitrification feed are given in Table C.9.4.11-1. No processes or activities associated with HLW vitrification that could result in isotopic enrichment or depletion have been identified (Carl et al. September 30, 1990).

Concentrations of fissile isotopes in the vitrification feed from Tank 8D-2 also are listed in Table C.9.4.11-1. From this table it may be seen that, even with maximum concentration and optimum moderation and reflection, an additional increase in concentration by greater than a factor of 20 would be necessary in order to exceed the criticality limits. Consequently, an inadvertent criticality in the vitrification process is not a credible event (Wolniewicz January 30, 1994).

The reactivity of HLW solids in the CFMT was evaluated as a function of the volume percent of water. The criticality evaluation was made using the Criticality Safety Analysis Sequence (CSAS25) within the SCALE-PC Modular Code System. The multi-group Monte Carlo code KENO-Va was then used by CSAS25 to determine the k_{eff} for an accumulation of fissile material solids in the bottom of a cylinder having the dimensions of the CFMT. Figure C.9.4.11-1 shows the k_{eff} as a function of the volume fraction of water in the bottom portion of the CFMT which also contains the fissile material. Infinite reflection by water on top and reflection by the steel vessel wall on the sides and bottom was assumed. As can be seen from the figure, the system is well within safe limits (Yuan February 1994). This evaluation is considered sufficiently conservative to bound the reactivity associated with unexpected or abnormal scenarios such as plateout in the process vessels, heel accumulation in the melter or elsewhere, or leakage to an uncontrolled area (e.g., a sump containing water). Lending credence to this statement are the following facts: 1) the concentrations shown in Table C.9.4.11-1 were calculated assuming that the feed solution is completely reduced to solids; 2) the critical limits shown in Table C.9.4.11-1 are for a homogeneous aqueous solution reflected by an effectively infinite thickness of water; 3) the boron present in the waste is not considered in the evaluation; and 4) as shown in Figure C.9.4.11-1, the maximum k_{eff} for the assumed configuration is relatively small (i.e., about 0.08) and decreases continuously with the addition of water.

In addition to the criticality evaluation described above, k_{eff} calculations have been performed to determine the reactivity of HLW glass canisters (Yuan January 1994). Again, the model was very conservative and did not consider the neutron-absorbing boron present in the vitrified waste. Other differences between the calculational model and the actual material composition were treated conservatively (i.e., they were made to overestimate k_{eff}). The conclusion of this analysis was that the concentration of fissile material in the WVDP HLW glass canisters is so low that, even for an infinite array of canisters, the k_{eff} is well below 0.1 with optimum geometry and water moderation.

Because of the relatively low concentration of fissile material in the vitrification feed solution, a criticality excursion is not a credible event at any point in the vitrification process or as a result of a conceivable process upset. Thus, the VF requires neither criticality alarm systems nor criticality detection systems.

C.9.5 Nonradiological Accidents

Emergency Prediction Information Code (EPIcode), version 5.04, was used to model the atmospheric dispersion of nonradiological materials. EPIcode is endorsed by the DOE as a useful tool for helping emergency planners estimate potential impacts from atmospheric releases of toxic substances. EPIcode uses a Gaussian plume model to calculate the peak ground-level concentrations downwind of a release. It allows the user to choose the meteorological and environmental conditions of the release, including the Pasquill-Gifford stability class (A-F), ground-level wind speed, terrain, effective release height, ambient temperature, and sampling time. EPIcode does not account for terrain effects, plume buoyancy, or wake effects due to nearby structures.

Although there are many other chemicals used in preparing batches of waste for vitrification, the two primary potential off-site hazards are nitric acid and nitrogen oxides. EBAs involving the release of these substances were analyzed to determine on-site and off-site consequences.

C.9.5.1 Nitric Acid (HNO_3)

A maximum allowable working volume of 6.52 m^3 (1,722 gal) of nominally 67 weight percent nitric acid may be stored in the Nitric Acid Day Tank (65-D-05) in the Cold Chemical Building. The greatest off-site hazard from nitric acid is the evaporation and dispersion of HNO_3 fumes from an uncontained liquid spill. As a result, the consequences of a nitric acid accident depend more on the "pool" area that is formed by the leak than the rate of acid leakage from the tank. The evaporation rate from a liquid pool is also a function of vapor pressure, molecular weight, temperature, and wind speed.

The postulated accident assumes a failure of the Nitric Acid Tank, which releases the total contents to the Cold Chemical Building. The tank is surrounded by a berm approximately 2.60 x 3.66 x 0.54 m (8.5 x 12 x 1.8 ft). This berm is notched and would hold 4.79 m^3 (1,265 gal), or roughly 73.5% of the acid, while the rest of the acid, 1.73 m^3 (457 gal), is assumed to form a pool in the common floor berm area in the Cold Chemical Building. The common floor berm area (which excludes the Nitric Acid Tank berm area and Caustic Day Tank berm area) is approximately 97.7 m^2 (1,052 ft^2). Dispersion modeling for a ground-level release from the two pools (i.e., the Nitric Acid Tank berm pool and common floor berm area pool) used meteorological conditions of 30°C (86°F), stability class F, wind speed of 1 m/sec (2.2 mph), and a vapor pressure of 4.1 mmHg (Perry's 1984). The concentrations of HNO_3 at the 640-m (2,100-ft) and 1,050-m (3,445-ft) boundaries are estimated to be 0.93 ppm and 0.41 ppm, respectively. Since these levels pose negligible health effects (47% and 21% of the TEEL-1 level, respectively), the Evaluation Guideline is easily met. (See Table C.9.5.1-1.) Temporary Emergency Exposure Limits (TEELs) describe "interim, temporary, or equivalent exposure limits for which official Emergency Response Planning Guidelines (ERPGs) have not yet been developed," and have been adopted by DOE's Subcommittee on Consequence Assessment and Protective Actions (SCAPA). ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing any effects other than mild, transient, adverse health effects or perceiving a clearly defined objectionable odor. ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

C.9.5.2 Oxides of Nitrogen (NO_x)

The maximum production rate of NO_x during vitrification is estimated to be 11 g/sec (1.5 lb/min). To eliminate NO_x, process gas leaving the Vitrification Cell is reacted with ammonia gas in a catalytic reactor to form nitrogen and water vapors, which are then released to the atmosphere through the Main Plant stack. If the NO_x abatement equipment was not operating, this release rate would result in NO_x levels of 0.015 ppm (less than 1% of TEEL-1) and 0.023 ppm on-site and off-site, respectively (Prowse February 1993). Therefore, loss of NO_x removal capability would not result in significant exposure or health effects to individuals beyond the site boundary (see Table C.9.5.2-1), nor would it result in exceeding the Evaluation Guideline.

C.9.6 Beyond Design Basis Accidents

The design bases for the VF include a DBT with a return frequency of 1E-06 per year and a DBE which has a return frequency of 5E-04 per year. The analyses described in Section C.9.4 demonstrated that the radioactivity released to the environs during either a DBT or a DBE would not expose members of the public to a calculated radiation dose which exceeded 30% of the Evaluation Guideline (Table C.9.4-1, Site Boundary Column). It is also useful to evaluate the consequences of earthquakes in a range from the design basis event (with a frequency of occurrence of 5E-04 per year) up to a beyond design basis earthquake (BDBE) with a return frequency of 1E-06 per year.

Table C.9.6-1 summarizes the scenarios and the radiological releases from earthquakes of a magnitude which exceeds the design basis value of 0.1 g. These data demonstrate that radiation doses from credible earthquakes with frequencies from 5E-04 per year through 1E-06 would be less than the Evaluation Guidelines. Specifically, the calculated dose to the maximally exposed off-site individual from a BDBE is less than 25 rem (0.25 Sv).

Key equipment, e.g, the Vitrification Cell Ventilation system, CFMT, MFHT, SFCM, etc., by definition are designed not to fail as a result of either a DBT or a DBE. The two key equipment pieces, CFMT and SFCM, were conservatively designed to survive without failure for a DBE with a return frequency of 5E-04/yr. A stronger earthquake, with an annual return frequency ranging from 5E-04 to 1E-06 per year, could cause additional failures which are considered credible. Four additional scenarios have been developed and analyzed in order to evaluate the potential consequences of these less likely earthquakes. Three of these scenarios relate to the Vitrification Cell. These are:

- Loss of all power, resulting in failure of in-cell off-gas jumper and Vitrification Cell Ventilation system inlet HEPAs (Crane Maintenance Room [CMR] and Transfer Tunnel), but with no tank failures.

- Loss of all power, off-gas jumper, inlet HEPAs, with simultaneous failure of the CFMT and SFCM and the Cell Ventilation blowers.

- Loss of all power, simultaneous SFCM and CFMT failure, but with the Vitrification Cell Ventilation system continuing to operate resulting in blow-out of HEPA filters due to high steam/water loading.

The fourth earthquake scenario considered is the collapse of the HLWIS roof. The energy evolved is not sufficient to rupture the stored HLW glass canisters. Hence, there is no radiological release. It is also assumed that this event causes the bridge crane to fall on the stored HLW canisters resulting in four canister failures.

C.9.6.1 Beyond Design Basis Tornado

The DBT is defined as having a 1E-06 per year frequency of striking the VF. With the additional factors developed in Section C.9.4.10 to reduce further the probability of the DBT causing significant damage, analysis of an even more severe tornado clearly is not required.

C.9.6.2 Beyond Design Basis Earthquake

A seismic event with a magnitude greater than the design basis acceleration of 0.1g could cause equipment failures that would result in more serious consequences than postulated in Section C.9.4, *Radiological Accidents*. The following scenarios are considered to bound the possible results of earthquakes with return frequencies in the range of 5E-04 to 1E-06 per year.

C.9.6.2.1 Loss of Power and Cell Inlet Filters

Section C.9.4.9 considered a total loss of power scenario in which unfiltered gas leakage from the cell to the atmosphere was calculated to be 3% of the SFCM gas release to the cell atmosphere. Although 11% of the Vitrification Cell air escaped, 73% of that flow was filtered by its backflow path through the cell inlet (CMR and Transfer Tunnel) HEPA filters.

For this analysis, because the initiating force is a BDBE, it could be assumed that the inlet ducts fail, so that the total outflow (11% of the contained Vitrification Cell volume) escapes to atmosphere. However, failure of these inlet ducts is not probable, based on seismic analysis that estimates they would survive at greater than ten times the force of a DBE, corresponding to a return frequency of approximately 1E-07 per year. However, it is useful to demonstrate that total failure of the Cell Ventilation system as a result of a BDBE would not have serious consequences. Therefore, for this BDBE scenario, it is arbitrarily assumed that the air inlet ducts and HEPA filters fail.

This event would result in four times the dose developed in Table C.9.4.9-1 for the design basis loss of power case. The off-site dose would be 110 mrem (1.1 mSv) (based on the ground-level χ/Q of 6.23E-04 sec/m^3 [1.8E-05 sec/ft^3] at the site boundary, 1,050 m [3,445 ft] away) to the maximum exposed individual, and the dose to the on-site worker would be 270 mrem (2.7 mSv) (based on a χ/Q of 1.49E-03 sec/m^3 [4.2E-05 sec/ft^3] at a distance of 640 m [2,100 ft]). These values are somewhat overstated, because the mitigating effects of dilution and delay introduced by the volume of the CMR and Transfer Tunnel have not been considered. Thus, these results would be representative of any scenario involving a direct path for out-leakage of contaminated air.

C.9.6.2.2 Simultaneous CFMT Slurry and SFCM Molten Glass Dump

The consequences of a DBE (Section C.9.4.3, SFCM Off-Gas Jumper Failure) are very low (0.05 mrem [5.0E-04 mSv] off-site), because the SFCM and CFMT are seismically restrained to prevent failure and because the Vitrification Cell confinement would remain fully operable.

A simultaneous CFMT slurry and SFCM molten glass dump, with a partial failure of the Vitrification Cell Ventilation system is also considered a potential result of a BDBE. The SFCM is restrained from falling by a support structure that would survive a greater than two times DBE corresponding to a return frequency of 8E-05 per year. However, the SFCM box failure point, though greater than the DBE of 5E-04 per year, has not been specifically developed. The two HLW slurry tanks of concern, the CFMT and the MFHT, rest on a common support structure that has a margin of safety to 1.4 times the DBE, equivalent to a return frequency of 4E-04 per year. It is assumed that this catastrophic event would occur with a limiting failure probability equivalent to the earthquake return probability of 4E-04 per year. However, failure probably would not occur at this frequency because of several conservative factors in this calculation. First the calculations do not predict failure, only that below this design basis value failure will not occur. Second, failure of the tank support structure does not directly cause tank failure. Third, all calculations were based on yield point, not ultimate strength, which adds a very important safety factor to the analysis.

Because it cannot be predicted whether the CFMT or the MFHT or both would fail, the most severe assumption is made, namely that the CFMT fails when filled to its maximum concentration, a condition that exists approximately 10% of the time. Dual failure of the CFMT and the MFHT, or single failure of the MFHT, would result in a lower slurry concentration than failure of the CFMT alone. Since the consequences are concentration-dependent, a lower curie release and dose also would result.

The accident is initiated by the simultaneous dumping of the CFMT and the entire SFCM molten glass inventory into the pit area of the Vitrification Cell. The slurry, floating on top of the molten glass, boils violently dispersing radioactive steam containing fine solid particulates throughout the cell.

The bounding ARF for a boiling solution has been reported in the DOE-HDBK-3010-94 as 2E-03 corresponding to a DF of 500. Although the SFCM feed is a heavy aqueous slurry mixture (not a solution) with essentially all of the radioactive material in the solid phase, this bounding DF of 500 is therefore a conservative value and certainly leads to an overestimate of the release.

Boiling, condensation, and transport of the steam generated in the Vitrification Cell have been analyzed in increments of one minute for the accident sequence during a time frame of fifteen minutes. The initial boil-up rate from the 4.6-m (15-ft) diameter glass pool is approximately 113 kg or 190 m^3 (250 lb or 6,700 ft^3) of steam per minute. As this steam fills the Vitrification Cell, a portion is condensed on the colder walls, equipment, and piping, and it is assumed that the condensed steam carries with it the proportional quantity of radioactivity. The resulting net steam displaces an air/steam mixture from the cell. In addition, the steam also heats the air, which expands further, contributing to cell atmosphere displacement. (The cell may pressurize from 12.7 mm to 38.1 mm [0.5 in to 1.5 in] water column, which is not sufficient to endanger the integrity of the cell windows or other cell components.) After approximately ten minutes, the boil-up rate has slowed and the condensation rate becomes greater than the expansion rate of the cell atmosphere. At this point, the net cell expansion turns negative, and air is drawn back into the cell, re-establishing its confinement function.

The net expansion of the cell atmosphere is always less than the induced 240 m^3/min (8,500 ft^3/min) air flow, so that if the Cell Ventilation system continued to operate there would be no release of radioactivity. However, failure of the Cell Ventilation system can be hypothesized either from its failure to operate, caused by the BDBE, or through HEPA filter blow-out resulting from the high water/wet steam loading to the filter. The resultant doses from these two failure scenarios are quite different, with the HEPA blow-out case and exhaust of 240 m^3/min (8,500 ft^3/min) of unfiltered cell air, resulting in higher doses.

A chronological outline of the key steps and parameters used in the analysis of the scenario involving loss of the Cell Ventilation system follows (Kupp August 26, 1993a; August 26, 1993b):

- At time zero, the CFMT, at maximum slurry concentration, and the SFCM fail and drop their full inventory on the Vitrification Cell floor, forming a 4.6-m (15-ft) diameter glass pool at 1,200°C (2,200°F), with the slurry floating on top and boiling. The boil-up rate is approximately 190 m^3 (6,700 ft^3) of steam/min, carrying with it associated radioactivity at an ARF of 2E-03 (DF of 500). The boiling continues until the total excess heat capacity of the glass, 1,200 to 100°C (2,200 to 212°F), is transferred to the steam. Since the reaction is concentration-dependent, dual failure of the CFMT and MFHT or single failure of the MFHT would result in lower slurry concentrations and hence a lower curie release rate and accident dose.

  It is also assumed that the BDBE caused the Cell Ventilation system to cease operating and that open paths out of the Vitrification Cell confinement would relieve the cell air expansion resulting from the steam addition and heating of the cell air.

- As the steam diffuses in the Vitrification Cell, it both displaces and heats the air, causing expansion. However, the volume expansion would be mitigated by partial condensation on the colder, less than 100°C (212°F) surfaces, e.g., walls, ceiling, equipment, structures, and piping. The net of these several counter-effects (e.g., boil-up, air expansion, condensation) peaks at nine to ten minutes after time zero, with a resultant maximum volume expansion of approximately 600 m^3 (21,000 ft^3). However, because of the sequential paths from the 2,600 m^3 (92,000 ft^3) Vitrification Cell through the CMR (850 m^3 [30,000 ft^3]), and in parallel, through the Transfer Tunnel (340 m^3 [12,000 ft^3]), the radioactive "steam" release from the confinement structures is substantially reduced. A minute-by-minute transport analysis calculation results in a total radioactive release equivalent of 30 m^3 (1,060 ft^3) of radioactive steam/water vapor.

- The radioactivity associated with the steam is removed when steam is condensed but no other fallout or solids deposition is assumed during the release and transport phase. After the steam (radioactivity) escapes the Vitrification Cell boundary, no further removal function is used, not even in the CMR and Transfer Tunnel, so that the subsequent off-site and on-site dose calculation is a conservative overstatement.

An alternative scenario in which the Vitrification Cell Ventilation system continues to operate could result in very minor off-site and on-site doses if the two-stage HEPA filters are functional. However, because of the water/steam loading following the simultaneous CFMT and SFCM dump, the differential pressure across these filters could be so high as to cause rupture. The differences from the above scenario are as follows:

- For the first several minutes after time zero, the cell Ventilation system and HEPA filters operate normally, removing 240 m^3/min (8,500 ft^3/min) of air. Very little steam gets to the HEPA filters in the Vitrification Cell, so there is no volume expansion of the Vitrification Cell air.

- Because of the high water loading, the first (in-cell) HEPA plugs and then fails after four minutes, and the second HEPA (ex-cell) fails after six minutes. Prior to this, the HEPA filters are effective in removing airborne radioactivity.

- Beyond the six minute point the blower continues to operate, sweeping air/steam/radioactivity out of the cell and discharging it from the stack on the roof of the Vitrification Building. This is considered an unfiltered ground level release. During the total time frame of 0-30 min, in-cell condensation of the steam continues as it did in the no-vent scenario, above. However, because of the sweeping effect of the 240 m^3/min (8,500 ft^3/min) flow, much of the unfiltered steam/radioactivity in the cell air would be released to the environment. A minute-by-minute transport analysis results in a total predicted radioactive release equivalent of 440 m^3 (15,700 ft^3) of radioactive steam/water vapor.

The off-site and on-site dose resulting from these two "dump" scenarios is a function of the volume of unfiltered steam/water vapor, which is released either for cell leakage in the scenario including loss of the cell Ventilation system, or from unfiltered blower discharge in the scenario in which the Cell Ventilation system continues to operate. Table C.9.6.2.2-1 summarizes the dose for a ground level release.

The radioactive steam/water vapor release of 30 m^3 (1,060 ft^3) for the scenario of the loss of the Cell Ventilation system, and the 440 m^3 (15,700 ft^3) for the scenario in which the Cell Ventilation system continues to operate are combined with the unit dose factors to determine the total on-site and off-site dose. These data are summarized in Table C.9.6.2.2-2. The maximum dose for a CFMT failure resulting from a BDBE is 23.6 rem (0.236 Sv) off-site (based on the ground-level χ/Q of 6.23E-04 sec/m^3 [1.8E-05 sec/ft^3] at the site boundary, 1,050 m [3,445 ft] away) and 56.4 rem (0.564 Sv) on-site (based on a χ/Q of 1.49E-03 sec/m^3 [4.2E-05 sec/ft^3] at a distance of 640 m [2,100 ft]). The doses from a MFHT failure would be about one-fourth of these values because of a lower radioisotope concentration. The doses in the case of failure of both tanks would result in intermediate values between the CFMT failure and MFHT failure cases.

C.9.6.2.3 Failure of HLWIS Roof

In a BDBE, the roof of the HLWIS could fail. Typically, this would be a partial failure, and much of the potential energy would be expended in cracking or bending rather than a free-fall drop. However, for a conservative analysis, the total roof slab is assumed to free-fall onto the HLW glass canisters, stacked in two layers. The energy from this free-fall drop would be equal to approximately 0.1 joules/cm^3 of glass. The 7-meter (23-ft) free-fall test drop to an unyielding surface, which the loaded HLW canisters survive intact, is equivalent to 0.18 joules/cm^3.

In addition to the fact that much of the roof drop energy potential would be used in bending/cracking, the top of the canisters and the rack would absorb much of the fall in yield compression. These effects would further minimize the likelihood of canister failures. A high concentrated impact could result from a crane drop accident below in which the consequence of release from the failure of a few canisters is developed.

C.9.6.2.4 Crane Falls in HLWIS

In a BDBE, it can be hypothesized that the bridge crane servicing this area could fall on top of the stored HLW glass canister array. Such a drop, depending upon the point(s) of impact, could result in failure of some of the canisters and a possible release of radioactivity.

Canister failure had been reviewed in Section C.9.4.6 in which the 7-m (23-ft) test drop with no failure was equated to an energy of 0.18 joules/cm^3. If the total energy of a crane drop is associated to this 0.18 joules/cm^3, or 1.3E+05 joules/canister, the equivalent of four canisters could be assumed to fail. Further, if 10% of this energy is assumed to be transferred to the contained HLW glass, an ARF (per DOE Handbook 3010-94) can be calculated. Both of these assumptions are estimated to be conservative. The storage racks and tops of the canisters (air space) would partially collapse under a crane impact and this bending/crushing action would absorb much of the failing energy. Further, the indirect impact to the glass would not cause maximum fines (<10 microns [<3.9E-04 in]) to be generated. Even if the stainless steel canister is cracked there still would be a significant confinement function.

Notwithstanding these mitigating functions, a release equivalent to 10% of bare glass with an energy input of 0.18 joules/cm^3 has been used to calculate an on- and off-site dose. It has also been assumed that the HLWIS confinement integrity is not maintained, i.e., a direct ground level release to the environment is assumed. The resultant off-site dose is 5.7 mrem (0.057 mSv) (based on the ground-level χ/Q of 6.23E-04 sec/m^3 [1.8E-05 sec/ft^3] at the site boundary 1,050 m [3,445 ft] away) and the on-site dose is 13.6 mrem (0.136 mSv) (based on a χ/Q of 1.49E-03 sec/m^3 [4.2E-05 sec/ft^3] at a distance of 640 m [2,100 ft]). No fall-out or other removal function is assumed in this dose development.

C.9.6.3 CFMT Steam and Slurry Release

The steam requirements of the Vitrification Cell are supplied from the WVDP Main Plant via the 690 kPag (100 psig) Vitrification Building Steam system. A 76-mm (3-in) steam supply line connects to the bottom CFMT steam coil jacket, which consists of half-circle profile 76-mm (3-in) diameter schedule 10 pipe with a wall thickness of 3.0 mm (0.12 in) welded to the 9.5-mm (0.375-in) tank wall in a spiral around the outside of CFMT bottom. This bottom CFMT jacket uses steam at approximately 690 kPag (100 psig). There is a similar pipe coil on the side of the tank, a helix design, that uses relatively low pressure (i.e., 103-138 kPag [15-20 psig]) steam and that can be independently controlled in both the heating and cooling cycle. Surrounding these two coils is a thin, 14 gage, stainless steel cover which holds the insulation in place. Although this cover is not designed as a full pressure confinement barrier it could serve this function for smaller steam leaks and therefore could mitigate, to some extent the consequences from larger leaks. Not withstanding the probability of some accident mitigation, a maximum coil/tank wall failure with an associated cover failure is hypothesized so as to bound the consequences of this slurry/steam release event.

The three factors that determine the CFMT steam break release and consequences are:

- CFMT slurry maximum concentration. (See Table C.9.4.1-1.)
- Steam release rate (calculations were based on the maximum release from the half-circle profile 76-mm (3-in) line.
- Fraction of HLW carried with the steam (determined by the geometry of the break and any local fallout characteristics of the HLW slurry, i.e., settling of solids in slurry).

The design requirement for steam to the CFMT during a typical concentration period is approximately 450 kg/hr (1,000 lb/hr), twice that which is the cycle basis for the time frame of the concentration phase as summarized in Table C.9.4.1-1. Steam flow to the CFMT jackets is controlled by pressure rather than by steam flow rate. On failure of both the coil and tank wall, allowing free discharge of steam and concentrated slurry to the cell, coil pressure would drop below 28 kPag (4 psig). At this value, the DCS control will automatically do the following: stop steam flow; close the return line from the coil; and open the valve to admit 172 kPag (25 psig) air to the coil in an attempt to return coil pressure to greater than 28 kPag (4 psig). Pressure at the release point will remain at approximately cell pressure.

Flow through the assumed release point of the half-circle profile, 76-mm (3-in) diameter pipe will be approximately 2,600 kg/hr (5,700 lb/hr).

The steam released to the Vitrification Cell will partially condense, leaving free water on the HEPA filters. The filters, which are sensitive to the steam, may partially plug. However, they are expected to tolerate the short steam release (the DCS was assumed to mitigate the release within 15 minutes) without failure.

Although there is no way to rigorously quantify the release from this hypothesized jet action, such a system could hardly be very efficient, so that only a relatively small amount of the slurry would become atomized and airborne. A dose estimate has been calculated for this situation, based on the following parameters:

- Maximum concentration in CFMT (see Table C.9.4.1-1) of 1.33E+02 Ci/kg water.
- Steam flow 2,600 kg/hr (5,700 lb/hr) for a 15-minute period.
- Steam atomizes 260 kg/hr (570 lb/hr) slurry, a total of 6.5 kg (14 lb) of slurry remains airborne. This source term results in a total release into the Vitrification Cell of 3.6E+02 Ci with the same radioisotopic distribution as in Table C.9.4.1-2.
- HEPA train DF is 1E+03 and (multiplied by) 1E+02; total of 1E+05.
- Rem/curie release conversion as in Table C.9.4.1-2.

The resultant off-site EDE is 1.1 mrem (0.011 mSv) to the maximally exposed individual and 2.7 mrem (0.027 mSv) to the on-site worker.

In the above calculational bases, the two critical criteria are the 15 minute duration of the steam release and the slurry atomization estimate of 260 kg/hr (570 lb/hr). Both directly affect the final dose consequence.

The fraction of slurry which could be atomized by a steam coil/tank wall failure is highly variable. Most dual failures, coil and tank wall, would result in no slurry release; local pressures tend to keep the slurry in the tank. Under unusual break geometries, a high steam velocity jet action might aspirate some HLW slurry from the CFMT. The efficiency of such a jet action would be extremely low, hence the release would be a very small fraction of the total steam flow. The value tabulated above is one percent. After the slurry is "atomized" no removal function (fall-out) is assumed in the Vitrification Cell, even though most of the dose-contributing isotopes are in the solid (particle) slurry phase.

This accident would result in a major steam cloud in the Vitrification Cell and would also be indicated by transients in the process instrumentation and a high delta pressure alarm, three independently observable effects. DCS actuation to shut off the steam flow within 15 minutes is a conservative estimate.

This scenario is not credible (i.e., less than 1E-06/year frequency of occurrence). The several probability factors that combine to make this an incredible event are listed in Table C.9.6.3-1.

C.9.7 Nonradiological Beyond Design Basis Accidents

Consistent with typical commercial industrial practice, toxicological hazards are evaluated if their frequency of occurrence is greater than 1E-04/yr (see Section C.9.1.1). Consequently, chemical accidents whose annual frequency are less than 1E-04 are considered BDBAs. The consequences of the four nonradiological BDBAs are summarized in Table C.9.7-1.

C.9.7.1 Anhydrous Ammonia Accidents

C.9.7.1.1 BDB Ammonia Tank Failure

The ammonia tank is designed with the following specifications:

- Design Pressure: 1,724 kPag (250 psig)
- Design Temperature: 43°C (110°F)
- Operating Pressure Range: 414-1,358 kPag (60 - 197 psig)
- Operating Temperature Range: 4-30°C (40-100°F)

Due to its hazardous contents, the storage tank design must comply with the requirements of ASME, ANSI, CGA, CFR, and NYSDEC. Because of the extraordinarily high number of regulations and design standards for the ammonia tank, a catastrophic failure of the tank was concluded to be a BDBA.

For this assessment (Lawrence 1992), the hazard has been identified as maximum physical tank capacity, 3.785 m^3 (1,000 gal), of anhydrous ammonia. The tank is 1.07 m (3.5 ft) in diameter and 5.2 m (17 ft) high. During VF operations, weekly deliveries of anhydrous ammonia are expected.

This analysis assumed the following physicochemical parameters (WHO 1986):

Normal Boiling Point: -33.35°C (-28.03°F)
Molecular Weight: 17.03 g/mol
Liquid Specific Gravity: 0.771 g/cc
Tank Vapor Pressure: 410 kPag (60 psig)
Liquid Specific Heat: 0.2537 BTU/lb-°F
Specific Heat Ratio for Gas: 1.3

The tank failure analyzed assumes that a hole 25.4 mm (1.0 in) in diameter is made in the liquid space at the bottom of the tank. This assumption minimizes ground pooling while maximizing the release rate. Due to its extremely low boiling point, compressed liquified anhydrous ammonia will immediately flash to vapor upon release. Therefore, diking is not required for containment of a spill following catastrophic failure of the tank.

The operations associated with the this system include storage and loading/unloading. These can be represented by tank failures and leaks, hose failures, and piping and process vessel failures. The following failure rates have been used (FEMA, 1989):

Pressure vessels: 1E-04/vessel-year
Piping: 1.5E-06/ft-year
Loading hoses: 1E-04/operation

These equipment failures do not cover all potential release scenarios; however, they do represent the more likely failures resulting in large atmospheric releases. The most frequent types of spills or discharges have minor consequences and conversely major spills and accidents generally have lower frequencies of occurrence.

The ground-level, sector average ammonia concentration for all sectors, stability classes, and average wind speeds as a function of frequency was calculated. The average concentration at the site boundary is 38 ppm and is displayed in Table C.9.7-1. The average sector risk (risk to an average individual), 1E-07 fatalities/year, is less than the DOE safety goal of 0.1% increase in risk of prompt fatality.

C.9.7.1.2 BDB Ammonia Loading Accident

The *Handbook of Chemical Hazard Analysis Procedures* gives the following failure rates for industrial uses at fixed facilities:

- Piping (if more than 30.5 m [100 ft]): 1.5E-04/ft-yr
- Loading hose (if used >10 times/yr): 1.0E-04/operation

The frequency of tank refills (approximately 52/yr) makes an accident during loading the most probable event, at 5.2E-03 failures per year. To prevent substantial leakage, external pipe and hose connections to the tank and the ammonia tank truck are protected by internal excess flow valves (ANSI K61.1-1989). Internally coupled to each tank, the valves are designed to close at a liquid exit rate of approximately 190 L/min (50 gpm). Because the ammonia is stored under pressure (minimum 414 kPag [60 psig]), catastrophic hose failure would generate sufficient liquid or vapor flow(s) to close the valves almost immediately. Less severe line breaks, however, may not result in sufficient flow to close the valve(s).

In the event of a hose failure (Bradley 1993), it is assumed that ammonia is released through the full hose diameter at the loading rate until the flow can be terminated. For conservatism, a bounding release rate of 190 L/min (50 gpm) was chosen for the loading accident in which one the excess flow valve on the tank or the tank truck failed to close. Average sector average concentration using the same methodology as was used in Section C.9.7.1.1 results of EPIcode dispersion simulations for a 190 L/min (50 gpm) continuous ground-level release are given in Table C.9.7-1. Assuming a failure rate of 1E-03/demand for each valve, the frequency of an excess flow valve failing to actuate during a loading hose failure is 5.2E-06/yr; failure of both excess flow valves has a frequency of 5.2E-09/yr.

In addition to the excess flow valves, the ammonia storage tank is equipped with an automatic water deluge system. The deluge system is designed to function primarily as a fire suppression system, but it can function as a gas absorber since ammonia is readily soluble in water. It consists of a metal frame around the outside of the tank that houses fog-spray nozzles and detectors. Upon detection of ammonia vapors or high temperatures, the system activates a 190 L/min (50 gpm) fog-spray to suppress a fire or ammonia leak. However, the effectiveness of deluge systems in mitigating an ammonia release is very difficult to accurately model. For this reason, and because the postulated hose failure could occur beyond the range of the deluge system, credit cannot be taken for it.

C.9.7.1.3 BDB Anhydrous Ammonia Tank Truck Accident

Weekly deliveries of anhydrous ammonia are expected during operation of the VF. Based upon the delivery frequency, the round-trip distance from the WVDP Parking Lot to the tank (805 m [2,640 ft]), and the 4E-7 accidents/mile probability of significant (>10% cargo loss) given in the *Handbook of Chemical Hazard Analysis Procedures*, the occurrence of a tanker truck accident on-site is 1.04E-05/yr. The consequences of this accident were not analyzed.

C.9.7.2 BDB Nitric Acid Tank Truck Accident

Weekly deliveries of nominally 67 weight percent nitric acid are expected during operation of the VF. Based upon the delivery frequency, the round-trip distance from the WVDP Parking Lot to the tank, and the 4E-7 accidents/mile probability of significant (>10% cargo loss) given in the *Handbook of Chemical Hazard Analysis Procedures*, the occurrence of a tanker truck accident on-site is 2.08E-05/yr.

The loading accident analyzed assumed loss of 15.9 m^3 (4,200 gal) - the largest quantity of acid that could be brought on-site to fill the Nitric Acid Day Tank. Throughout the vitrification campaign, nitric acid deliveries will be made on demand. Many of these shipments will be of the amount needed to refill the tank; however, the acid distributor cannot always guarantee that only the needed amount of acid will be brought on-site, so some deliveries could be made from a full tanker.

The nitric acid tank truck is equipped with excess flow valves that actuate in the event of a hose failure, preventing large releases to the atmosphere. Without the existence of an outside berm, however, an acid leak from the tank truck would not be contained as well as a tank leak. The total area of a spill of the entire contents of the tank truck, assuming a 10-mm (0.4-in) depth, is 1,600 m^2 (17,200 ft^2). The consequences of this accident under conditions of PGSC F, 1 m/s (2.2 mph) wind are given in Table C.9.7-1.

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Table C.9.1.1.1-1

Comparison of EGs to ANSI/ANS 51.1

Frequency Range (Events/Yr)	WVDP Probability Category	WVDP EGs (rem)	ANSI 51.1 Criterion Category	ANSI 51.1 Criterion (rem)
1 to 1E-01	Normal Operations	EPA and Other Legal Limits on Normal Emissions	Plant Condition 1 & 2	10 CFR 50 App. I Limits on Normal Emissions
1E-01 to 1E-02	Anticipated Events	0.5 (DOE Order 5400.5)	Plant Condition 3	2.5 (10% of 10 CFR 100)
1E-02 to 1E-04	Unlikely Events	5 (10 CFR 72)	Plant Condition 4	6.25 (25% of 10 CFR 100)
1E-04 to 1E-06	Extremely Unlikely Events	25 (10 CFR 100)	Plant Condition 5	25 (10 CFR 100)

Table C.9.1.1.1-2

Illustrative Accident Frequency and MOI Dose

Accident Frequency (yr^{-1})	MOI Dose (rem)
1	0.4
0.1	4
1E-02	40
1E-03	400
1E-04	4000
1E-05	40,000
1E-06	400,000

Table C.9.3-1

Process Hazard Analysis for the HLW Transfer Trench, Pump Pit & Diversion Pit

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Radioactive contamination and high radiation exposure rates	Leakage of HLW slurry from transfer pipe	1) Double-walled confinement piping 2) Liquid level detectors 3) Concrete trench around piping 4) Shielding over trenches 5) HLW transfer in progress one 1-2% of time 6) Transfer pipe is purged of HLW after each transfer	Low - minor operator exposure	Extremely unlikely	Verify that leak detectors are operable.
	External gamma radiation	All items except 2, above	None - negligible operator exposure	Unlikely	Verify that procedures provide adequate protection (shielding) of workers.

Table C.9.3-1 (Concluded)

Process Hazard Analysis for the HLW Transfer Trench, Pump Pit & Diversion Pit

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Radioactive contamination and high radiation exposure rates	Leakage of HLW slurry from jumper in pit	1) Concrete pit with stainless steel liner 2) Drain which routes leak back to HLW tank 3) Liquid level detectors at drain 4) Shield over pit 5) Sealed pit cover 6) Ventilation providing a slight negative pressure in pit 7) HLW transfer in progress one 1-2% of time 8) Transfer pipe is purged of HLW after each transfer	Low-minor operator exposure	Unlikely	Verify that leak detectors are operable.
	External gamma radiation	All items except 3, above	None-negligible operator exposure	Unlikely	Verify that procedures provide protection (shielding) of workers

Table C.9.3-2

Process Hazard Analysis for the Vitrification Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Loss of HLW from CFMT (19,000 L)	Leak due to corrosion	1) Liquid level indicators 2) All leakage would be confined to pit 3) Hastelloy C-22 susceptible to negligible pitting or crevice corrosion 4) Zone I ventilation area	(None) negligible operator exposure	Extremely unlikely	1) Immediate stoppage of transfer. 2) Recovery will be to clean the slurry from the pit floor and replace the CFMT with another vessel.
	Rupture of vessel with slurry at maximum concentration	Item 2, above	(Low) minor on-site impact	Extremely unlikely	Items 1 and 2, above. Note: Complete loss of CFMT contents analyzed in section C.9.4 as EBA.
Loss of HLW from MFHT (19,000 L)	Leak due to corrosion	1) Liquid level indicators 2) 304L SS susceptible to negligible pitting or crevice corrosion 3) Leakage would be confined to pit 4) Zone I ventilation area	(None) negligible operator exposure	Extremely unlikely	1) Immediate stoppage of transfer. 2) Recovery will be to clean the slurry from the pit floor and replace the MFHT with another vessel. Note: Complete loss of MFHT contents analyzed in section C.9.4 as EBA.
Loss of HLW from SFCM (860 L)	Leakage of molten glass to cell floor	1) Melter Viewing System 2) CCTV 3) Viewing windows 4) Cooling jacket mitigates release	(None) negligible operator exposure	Extremely unlikely	1) Immediate stoppage of melter feed 2) Bring SFCM to an idling condition. Note: Complete loss of SFCM contents without stoppage of feed is analyzed in Section C.9.4 as EBA.

Table C.9.3-2 (Continued)

Process Hazard Analysis for the Vitrification Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Escape of SFCM Off-Gas to Vit Cell	Off-Gas jumper failure	Items 1, 2, and 3, above, and 4) A decreased pressure profile of the OGTS would alert operators 5) Visual observation of steam to Vit Cell 6) Secondary confinement in Vit Cell with double HEPA filtration	(None) negligible on-site and off-site impact	Unlikely	Same as above. Note: Catastrophic off-gas jumper failure without feed stoppage is analyzed in Section C.9.4 as EBA.
	Loss of Negative Pressure in SFCM (Instrument Control Failure)	1) Pressure alarm would alert operators 2) Visual observation of steam to Vit Cell 3) Secondary confinement in Vit Cell with double HEPA filtration	None - some additional contamination of Vit Cell but fully confined, so negligible on-site and off-site impact	Anticipated	1) Operator would take action to stop feed to SFCM and determine cause. 2) Negligible release (see major release to cell EBA analysis in Section C.9.4.3).
HLW into Operating Gallery	Backup from CFMT, MFHT through steam/ instrument/sampling lines	1) Instrument control on automatic valves for line isolation and purging (jet steam lines) 2) Lines in gallery are not open, radioactive liquid would be contained 3) Radiation alarms would cause gallery evacuation	Low - High gamma radiation level in operating gallery, but no release to atmosphere and minimum operator exposure due to radiation alarm	Anticipated	After evacuation and shutdown cause would be determined and corrected.
Radioactive Contamination in Operating Gallery	Loss of confinement in maintenance/repair operations	1) Maintenance procedures minimize the possibility of contamination 2) Close health physics technician control when contamination is possible	Low - Possible minor personnel contamination, with decontamination efforts as necessary under health physics technician supervision	Anticipated	Normal operating/ maintenance procedures minimize release magnitude and consequences.

Table C.9.3-2 (Continued)

Process Hazard Analysis for the Vitrification Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Radioactive Contamination in Operating Gallery (continued)	Backup through leaking line seals (e.g., electrical) in an equipment (SFCM) pressurization incident	1) Normal negative pressure control prevents backflow 2) A possible pressure transient would be short duration 3) Radiation alarms would cause gallery evacuation	Low - Possible minor personnel contamination, with decontamination efforts as necessary under health physics technician supervision	Anticipated	Evacuation and decontamination under appropriate controls
Spillage of Molten Glass	Canister overflow	1) Canister turntable is completely enclosed 2) Glass holdup reservoir	(None) negligible on-site and off-site impact	Anticipated	If this event occurred the feed would be stopped. The consequence (dose) from this event would be bound by a complete melter loss of molten glass. Note: Complete loss of SFCM contents analyzed in section C.9.4 as EBA.
Hydrogen Deflagration in CFMT or MFHT	Hydrogen build-up due to inadequate tank ventilation	1) No ignition source 2) Long time (4 to 20 days) to build-up to LEL, assuming no inleakage to tank. 3) Instrument probe bubbler purge rate is 4 times that required to keep level less than LEL 4) Significant in leak exists to tank (e.g. agitator seal) due to 9-inch negative tank pressure 5) Tank void volume changes during normal operations cause air changes 5 times that required to stay below LEL	1) Deflagration would be contained by vent header and blow out to waste header 2) Maximum deflagration (optimum H_2 conc.) pressure would not exceed yield strength of tanks 3) Worst case is tank breaches and contents leak to Vitrification Cell pit.	Extremely unlikely	Maintain probe bubbler purge systems and vessel off-gas system operational.

Table C.9.3-2 (Continued)

Process Hazard Analysis for the Vitrification Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Loss of vitrified HLW from filled canister	Canister drop	1) Canisters are made of tough 304-SS approximately 0.34-cm thick 2) HLW incorporated in glass matrix	(None) negligible impact	Extremely unlikely	The canisters are designed not to fail from a 7-m drop.
	Heavy object dropped on canister	Items 1 and 2, above	(None) negligible impact	Extremely unlikely	Note: Damage to glass canisters is analyzed in section C.9.4 as EBA.
Loss of confinement of airborne radioactivity	HEPA failure (blow-out)	Operators monitor pressure loss	(Low) negligible off-site impact	Unlikely	Operators would recognize pressure changes and or radiation monitors and secure the ventilation. Note: HEPA filter blow-out accidents analyzed in section C.9.4 as EBA.
	Loss of power	1) Confinement structures 2) Passive ventilation components	(None) negligible impact	Unlikely	Note: Loss of power analyzed in section C.9.4 as EBA.
In-Cell Fire	Failure of motors, relays, etc.	1) Minimal sources of combustible material 2) 3/4-in tempered glass cover on inner-face of shield windows 3) High flashpoint of oil 345°F 4) Operations are visually monitored	(None) negligible impact	Unlikely	Operators would secure the Vit Cell Ventilation System.
In-Cell Fire	Mineral oil in shielding windows	Items 1, 3, and 4, above	(None) negligible impact	Extremely unlikely	

Table C.9.3-2 (Concluded)
Process Hazard Analysis for the Vitrification Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Ex-Cell Fire	Failure of motors, transformers, etc.	1) Minimal sources of combustible material 2) Concrete shield walls 3) Integrity of shield windows exposed to temperature of 1,100°C (2,000°F) for over 3 hrs	(Low) minor on-site impacts	Unlikely	Conceivable ex-cell fires would not impair confinement integrity.
	Combustible materials, paper	Items 1, 2, and 3, above	(Low) minor on-site impacts	Unlikely	Same as above.

Table C.9.3-3

Process Hazard Analysis for the Waste Canister Transfer Tunnel

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Transfer Cart failure (4 canister approx. 1.2×10^5 Ci Cs-137)	Loss of power	1) Four completely independent drive trains 2) Remote recovery capabilities	(None) minimal impact	Unlikely	An existing tethered cart is available in the EDR for retrieving the failed cart.
	Loss of signal to antennas	Item 2, above	(None) minimal impact	Unlikely	Same as above.
Failure of Transfer Tunnel Shielding Doors	Failure of ball screw drives	Operations viewed from window of the Vit Cell or HLWIS	(None) minimal impact	Unlikely	In the event of a shield door failure (open or closed), repairs would be performed remotely.
	Transfer cart jammed in door	Shield doors are interlocked with the transfer cart control software	(None) minimal impact	Extremely unlikely	Provisions have been made to remove damaged cart remotely.

Table C.9.3-4

Process Hazard Analysis for HLWIS

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Release of vitrified HLW from ruptured canisters	Heavy object dropped on canister	1) Visual inspection 2) HEPA filtration to remove released radioactivity (glass matrix) 3) Glass in a relatively stable, non-dispersible waste form	(None) negligible impact	Extremely unlikely	Visual inspection of damage to canister could result in the canister being remotely overpacked. Note: Roof and crane drop analyzed in Section C.9.6.2 as a BDBE accident.
Loss of confinement/shield integrity from damage to concrete shield walls	1) Decay Heat	1) HVAC 2) Low thermal heat from canisters 3) High specific heat value for cell concrete and glass waste form	(None) negligible impact	Extremely unlikely	Calculated heat generation from canisters has demonstrated negligible impact to concrete walls.

Table C.9.3-5

Process Hazard Analysis for the Cold Chemical Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Leakage of hazardous chemicals from slurry tanks (65-D-02,-03,-04)	Heavy object falling on tanks due to seismic event	1) Collection of slurry in sump/bermed floor 2) HVAC 3) 304L SS tankage	(Low) minor on-site impacts	Extremely unlikely	1) Immediate stoppage of transfers. 2) Recovery will be to clear the slurry from the floor and replace the damaged tank.
	Overfill	Items 1 and 2, above, and 3) Bubbler level probes 4) High-level alarm	Same as above	Anticipated	Items 1 and 2, above.
Leakage of hazardous chemicals from day tanks (65-D-05,-06)	Seismic event	1) Collection of liquid in sump/bermed floor 2) 304L SS tankage	(Low) minor on-site impacts	Unlikely	1) Immediate stoppage of transfers. 2) Recovery will be to clean the spill from the floor and replace the damaged tank.
	Overfill	1) Collection of liquid in sump/bermed floor 2) HVAC 3) High-level alarms	Same as above	Anticipated	Items 1 and 2, above.

Table C.9.3-5 (Continued)
Process Hazard Analysis for the Cold Chemical Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Leakage of hazardous chemicals from decon tanks (65-D-07,-08,-09)	Seismic event	1) Collection of liquid in sump/bermed floor 2) HVAC 3) 304L SS tankage	(Low) minor on-site impacts	Unlikely	1) Immediate stoppage of transfers. 2) Recovery will be to clean the spill from the floor and replace the damaged tank.
	Overfill	Items 1 and 2, above, and 3) High-level alarms	Same as above	Anticipated	Item 1, above, and 2) Recovery will be to clean the spill from the floor.
Leakage of hazardous chemicals from drain tank (65-D-01)	Seismic event	1) Collection of liquid in sump/bermed floor 2) HVAC	(Low) minor on-site impacts	Unlikely	1) Immediate stoppage of transfers. 2) Recovery will be to clean the spill from the floor and replace the damaged tank.
	Overfill	Items 1 and 2, above, and 3) Level detectors	Same as above	Anticipated	Item 1, above, and 2) Recovery will be to clean the spill from the floor.
Airborne chemical contamination from malfunction of Vac-U-Max Pneumatic Transfer System	Rupture of primary filter bag	1) Broken bag detector 2) Alarm on main control panel	(Low) minor on-site impact	Anticipated	1) Immediate stoppage of transfers. 2) Repair filter bag.

Table C.9.3-5 (Concluded)
Process Hazard Analysis for the Cold Chemical Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Leak of nitric acid day tank	Seismic event	1) Collection of liquid in sump/bermed floor 2) HVAC	(Low) minor on-site impact	Unlikely	1) Immediate stoppage of transfers. 2) Recovery will be to clean the spill from the floor.
	Overfill	Items 1 and 2, above, and 3) Level detectors	Same as above	Anticipated	1) Immediate stoppage of transfers. 2) Recovery will be to clean the spill from the floor.

Table C.9.3-6

Process Hazard Analysis for the Off-Gas Trench and 01-14 Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Release of contaminated off-gas	Rupture of ex-cell off-gas duct	1) In-cell Prefilter removes almost all particulate radioactivity 2) Duct is insulated 10-in 304 SS located in a concrete trench 3) Negative pressure in duct due to system exhaust blower	(Low) minor operator exposure	Unlikely	Maintain operation of system blowers while repairing leak.
External radiation exposure from contained radioactive off-gas	Lack of trench shielding	1) Off-gas duct 2) Same as item 1 above	(None) negligible operator exposure	Unlikely	Radioactivity in off-gas duct does not present an external exposure problem.
Excessive NO_x emissions from plant stack	Failure of selective catalytic reactor	1) NO_x analyzer on the reactor outlet monitors 2) Redundant catalytic reactor	(Low) minor operator exposure	Unlikely	Should the operating reactor lose efficiency, the spare selective catalytic reactor can be remotely valved into service.
Excessive NH_3 emissions from plant stack	Failure of selective catalytic reactor	1) Ammonia analyzer on the reactor outlet monitor 2) Redundant catalytic reactor	(Low) minor operator exposure	Unlikely	If operating reactor fails, the spare selective catalytic reactor can be remotely valved into service.
Release of NH_3 or NO_x into the 01-14 Building	Failure of piping or other component	1) The barrier provided by the piping and components 2) NH_3 and NO_x detectors in the 01-14 Building	(Low) minor operator exposure	Unlikely	Validate alarm, determine cause, take proper actions, investigate and correct. Operators will be trained in proper response to alarms.

Table C.9.3-6 (Continued)
Process Hazard Analysis for the Off-Gas Trench and 01-14 Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Fire in 01-14 Building	Failure of motors, relays, etc.	1) Minimal sources of combustible material 2) Area is accessible for inspection and maintenance by operators	None - negligible impact	Unlikely	Standard manual fire fighting techniques could be used due to the low inventory and contained nature of radioactive isotopes in the building.
Fire in off-gas duct	Build up of ammonium nitrate in off-gas duct downstream of NO_x reactors.	1) Process parameters, including unreacted ammonia, are carefully monitored and alarmed downstream of the NO_x reactor. 2) Analysis shows that normal process parameters must be grossly exceeded before build-up would occur 3) Fire in the off-gas duct would not spread due to lack of nearby combustibles 4) Potential build-up point is downstream of all radioactive components of the system.	Low - minor on-site impacts	Extremely unlikely	
Ammonia Fire	Ignition of ammonia released from storage tank	1) Ammonia will not sustain a fire without an external ignition source 2) Tank is located outside with no combustibles nearby 3) Tank has an automatic water deluge fire protection system 4) Relief valves are exhausted above the nearby building height	None - negligible impact	Extremely unlikely	A fire would require a breach of the pressure vessel and a continuous ignition source

Table C.9.3-6 (Concluded)
Process Hazard Analysis for the Off-Gas Trench and 01-14 Building

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Airborne ammonia at high ambient concentration	Release of ammonia from storage tank	1) Design and construction in accordance with ASME Section VIII - Division I, 29 CFR 1910.111, Compressed Gas Associate (CGS) Pamphlet G-2, and ANSI Pamphlet K61.1. 2) All process lines are equipped with excess flow control valves 3) Vehicle barriers are in place to protect the tank and excess flow control valves 4) No potential of suspended loads above the tank.	Moderate - Potentially lethal concentrations of ammonia released on-site.	Extremely unlikely	This is a hazard routinely encountered by the public. Note: Leakage analyzed as BDB accidents in Section C.9.7.
	Overfill of storage tank	1) Redundant tank relief valves which vent above the adjacent building roof-line 2) Local level indicator	Low - Minor concentrations of ammonia released to atmosphere	Anticipated	This is a hazard routinely encountered by the public.

Table C.9.3-7

Process Hazard Analysis for Vitrification Support Systems from Main Plant

Hazard	Cause	Protection/Mitigating Systems	Consequence	Frequency	Action Item/Comment
Loss of instrument air	Air supply system failure or loss of site power	1) High Pressure Air System provides the motive force to automatically position HVAC control actuators to safe shutdown position. 2) Header sensors alarm when system pressure drops to a preset level 3) Process operations are discontinued until normal supply is resumed 4) Back-up compressors are in place (if site power is available)	None - negligible operator exposure	Anticipated	The most likely cause of this event is site power failure. Compressors do not require stand-by power because back-up is provided by the High Pressure Air System.
Loss of utility air	Air supply system failure or loss of site power	1) Header sensors alarm when system pressure drops to a preset level 2) Process operations are discontinued until normal supply is resumed 3) Back-up compressors are in place (if site power is available)	None - negligible operator exposure	Anticipated	The most likely cause of this event is site power failure.
Loss of steam	Boiler or supply line failure	1) Two redundant natural gas-fired boilers with the ability to operate on diesel fuel as an alternate fuel 2) Steam does not perform any safety related function	None - delays in processing operations	Anticipated	Outages will be planned when maintenance is necessary.
Vit process upsets due to loss of cooling water	Failure of closed-loop cooling water system	1) Automatic switch-over to a back-up pump which is supplied by stand-by power. 2) CLCW system does not perform any safety related function	None - delays in processing operations	Anticipated	Outages will be planned when maintenance is necessary.

Table C.9.4-1

Evaluation Basis Accidents

SAR Section	Event	Bases for Accident	Frequency of Occurrence	Effective Dose Equivalent mrem with HEPA/mrem without HEPA		REMARKS
				On-Site (640 m)	Site Boundary	
C.9.4.1	CFMT Slurry Release	Entire batch of HLW slurry released from CFMT at maximum concentration/temperature.	EU	1.7E-01 --------- 1.7E+04	7.0E-02 -------- 7.0E+3	Maximum slurry concentration occurs 10% of time, reducing probability of this event.
C.9.4.2	Loss of CFMT Vent Condenser Cooling	Boil-up from the CFMT escapes via Vitrification and Main Plant stacks.	EU	1.2E-01 -------- 1.2E+04	1.7E+00 -------- 6.7E+3	Alarms would cause operator to shut off steam in less than 2 hours.
C.9.4.3	SFCM Off-Gas Jumper Failure	Following failure, normal feed and off-gas flow assumed to continue for 2 hours.	U	1.1E-01 -------- 1.1E+04	4.6E-02 -------- 4.6E+03	Operator action to stop slurry feed would reduce consequences.
C.9.4.4	Molten Glass Spill from SFCM	Rupture of SFCM dumps total melter inventory to cell floor.	EU	3.9E-02 -------- 3.9E+03	1.4E-02 -------- 1.4E+03	This event bounds all other less significant molten glass spills.
C.9.4.5	Steam Explosion in SFCM	Steam explosion in SFCM ruptures vessel and dumps the glass while slurry feed continues for 2 hours.	EU	1.3E-01 -------- 1.3E+04	4.6E-02 -------- 4.6E+03	Doses are reduced to 1/3 if feed is stopped following explosion.
C.9.4.6	HLW Canister Drop	10 m drop causes canister rupture and release of fine glass particulates.	U	4.6E-03 -------- 4.6E+02	1.8E-03 -------- 1.8E+02	
C.9.4.7.1	Process Off-Gas HEPA Filter Blow-out	Rupture/blowout of in-cell HEPA loaded with 90 Ci Cs-137	U	NA -------- Elevated stack release	NA -------- 2.0E+02	Also assumes failure of ex-cell HEPAs.
C.9.4.7.2	Vit Cell HVAC HEPA Filter Blow-Out	Rupture/blowout of in-cell HEPAs loaded with 9 Ci Cs-137 each (10 R/hr at 0.3 m).	U	NA -------- 5.5E+02	NA -------- 2.3E+02	Also assumes failure of ex-cell HEPAs.

Table C.9.4-1 (Concluded)
Evaluation Basis Accidents

SAR Section	Event	Bases for Accident	Frequency of Occurrence	Effective Dose Equivalent mrem with HEPA/mrem without HEPA		REMARKS
				On-Site (640 m)	Site Boundary	
C.9.4.8	Loss of Vit Cell Coolers	Failure of coolers or cooling water supply.	U	----	----	No release if coolers are only failure and vent system continues to operate.
C.9.4.9	Loss of Vitrification Facility Power	All power, including back-up ventilation systems, is lost.	U	NA -------- 6.6E+01	NA -------- 2.8E+01	Loss of all back-up power systems is unlikely.
C.9.4.10	Tornado	Design Basis Tornado missile penetrates confinement barrier.	I	----	----	Dose would be equivalent to two days normal operation; probability much less than 10^{-6}/yr.
C.9.4.11	Nuclear Criticality	Nuclear criticality in the vitrification cell and HLWIS is not credible.	I	----	----	Concentration of fissile isotopes in vitrification feed and product is insufficient to support criticality.
C.9.5.1	Nitric Acid Day Tank	Failure of Day Tank	EU	0.93 ppm	0.41 ppm	On and off-site concentrations too low for any consequences.
C.9.5.2	Oxides of Nitrogen	Failure of selective catalytic reactor.	U	0.023 ppm	0.015 ppm	On and off-site concentrations too low for any consequences.

Unlikely (U), Extremely Unlikely (EU), and Incredible (I) as defined in Section C.9.3.

Table C.9.4.1-1

CFMT - Processing Cycle Data

	Initial/Final Condition	Transfer From 8D-2	Recycle from SBS	Concentration Phase	Glass Former Addition and Holding
Time Frame					
Hours	8	1	<<1	80	87
% of Cycle Time	5	<1	<<1	45	49
Physical Properties				Range	Average
Volume - Liters	1,136	13,053	5,995	20,031 - 4,315	14,399
Mass - kg					
H_2O	768	12,058	5,990	18,777 - 2,870	9,533
Solids	827	2,983	60	3,995	10,841
Total	1,595	15,041	6,050	22,772 - 6,865	20,374
% Solids	48	20	~1	17 - 58	53
Temperature °F	90-130	130	130	215 - 230	90 - 130
Specific Heat - BTU/lb-°F	0.59	0.84	1.0	0.86 - 0.53	0.57
Enthalpy-BTU >100°F	6.2E+04	8.4E+05	4.0E+05	4.8E+06 - 9.0E+05	7.7E+05
Radioisotope Data					
Total Ci	2.89E+04	3.54E+05	3.6E+03	3.83E+05	3.83E+05
Ci/kg Water	3.76E+01	2.94E+01	6.0E-01	2.04E+01 - 1.33E+02	4.02E+01
Am-241 Ci	5.52E+01	6.77E+02	2.2E+00	7.32E+02	7.32E+02
Ci/kg Water	6.68E-02	5.61E-02	3.7E-04	3.90E-02 - 2.55E-01	7.68E-02

Table C.9.4.1-2

Data Summary for CFMT Spill at Maximum Slurry Concentration
(4,300 L, 100°C, 3.83E+05 Ci)

Radionuclide	Ci in Spill	Ci Released to Cell Atmosphere	Rem at Site Boundary per Ci Released at Ground Level	EDE at Site Boundary (mrem)
H-3	3.18E-03	4.88E-04	1.30E-05	6.34E-06
C-14	7.72E-03	4.17E-07	4.35E-04	1.81E-12
Sr-90	9.18E+04	4.96E+00	2.71E-01	1.34E-02
Ru-106	1.93E-01	1.04E-05	9.15E-02	9.52E-09
I-129	2.48E-03	1.34E-07	3.73E-02	5.00E-11
Cs-137	9.88E+04	5.34E+00	6.69E-03	3.57E-04
Pu-238	1.14E+02	6.16E-03	9.50E+01	5.85E-03
Pu-239	2.23E+01	1.20E-03	1.06E+02	1.27E-03
Pu-240	1.63E+01	8.80E-04	1.06E+02	9.33E-04
Pu-241	1.11E+03	5.99E-02	2.24E+00	1.34E-03
Am-241	7.32E+02	3.95E-02	1.07E+02	4.24E-02
Cm-244	1.05E+02	5.67E-03	5.60E+01	3.17E-03
TOTAL	3.83E+05			6.91E-02

Table Bases:

- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE). H-3, C-14, Ru-106, and I-129 have also been included to demonstrate their small contribution.
- Release to the cell atmosphere is due to splashing and evaporation on cooling from 100°C and 38°C. The combination of these two mechanisms results in an airborne release fraction (ARF) of 5.4E-05 for all nuclides except H-3. For H-3, the DF for evaporation is 1.
- The curie release from the Vit Cell to the environment is through two stage HEPA filtration with a combined DF of 1E+05 for all isotopes except H-3, which is 1.
- The rem/curie conversion factor is based on dose conversion factors from DOE/EH-0070 & 0071, and meteorology of 1 m/sec, PGSC F, and a χ/Q of 6.23E-04 sec/m3.
- On-site dose at 640 m is 2.39 times the off-site dose at 1,050 m based on the χ/Q ratio for ground level releases. Therefore, the total on-site dose would be 1.65E-01 mrem.
- The immediate decay products of Sr-90 and Cs-137, which are included in the rem/Ci conversion factors, double the curies listed for these two isotopes as indicated in the TOTAL.

Table C.9.4.2-1

Data Summary for Loss of CFMT Vent Condenser Cooling

Radionuclide	Maximum Concentration in Slurry (Ci/kg)	Ci per 100 lb steam	Ci from Vit Stack (Ground Level)	EDE at Site Boundary from Vit Stack (mrem)	Ci from Process Vent/Main Stack	Ci from Waste Header/8D-4/Main Stack	EDE at Site Boundary from Main Stack (mrem)
H-3	8.22E-06	3.73E-04	8.95E-04	1.17E-05	3.73E-03	2.83E-03	9.26-E06
C-14	2.69E-06	1.22E-07	2.93E-12	1.28E-12	1.22E-12	9.27E-10	4.37E-11
Sr-90	3.20E+01	1.45E+00	3.48E-05	9.40E-03	1.45E-05	1.10E-02	3.21E-01
Ru-106	6.72E-05	3.05E-06	7.32E-11	8.20E-09	3.05E-11	2.32E-08	2.81E-07
I-129	8.64E-07	3.92E-08	9.41E-13	3.59E-11	3.92E-13	2.98E-10	1.23E-09
Cs-137	3.44E+01	1.56E+00	3.75E-05	2.80E-04	1.56E-05	1.19E-02	9.57E-03
Pu-238	3.97E-02	1.80E-03	4.32E-08	4.13E-03	1.80E-08	1.37E-05	1.41E-01
Pu-239	7.77E-03	3.52E-04	8.46E-09	8.96E-04	3.52E-09	2.68E-06	3.06E-02
Pu-240	5.68E-03	2.58E-04	6.18E-09	6.55E-04	2.58E-09	1.96E-06	2.24E-02
Pu-241	3.87E-01	1.75E-02	4.21E-07	8.74E-04	1.75E-07	1.33E-04	2.99E-02
Am-241	2.55E-01	1.16E-02	2.78E-07	3.00E-02	1.16E-07	8.79E-05	1.03E+00
Cm-244	3.66E-02	1.66E-03	3.98E-08	2.23E-03	1.66E-08	1.26E-02	7.64E-02
TOTALS	1.33E+02	3.05E+00	9.68E-04	4.85E-02	3.76E-03	2.60E-02	1.66E+00

Table Bases:

- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE). H-3, C-14, Ru-106, and I-129 have also been included to demonstrate their small contribution to the total dose.
- The immediate decay products of Sr-90 and Cs-137, which are included in the dose calculations, double the curies listed for these two isotopes as indicated in the TOTAL Ci/kg.
- Maximum concentration in slurry based on Ci in the 2,870 kg spill from Tables C.9.4.1-1 and C.9.4.1-2.
- Ci/100 lb steam based on boiling partition coefficient of 1E-03 (except 1.0 for H-3).
- Vitrification stack release based on 240 lb steam/2 hr and HEPA DF = 1E+05 for all isotopes except H-3, which is 1.0.
- Vitrification stack EDE based on χ/Q of 6.23E-04 sec/m^3 at 1050 m NW.
- Airborne concentration to dose conversion based on DOE/EH-0070 & 0071.
- Main stack releases based on 1000 lb steam from process vent with demister DF = 10 and HEPA DF = 1E+05 plus 760 lb steam from 8D-4 with DF = 1E+03 (except for H-3 with all DFs = 1)
- Main stack EDE based on χ/Q of 6.72E-05 sec/m^3 at 1700 m NE.
- On-site dose at 640 m is 2.39 times the off-site dose at 1,050 m based on the χ/Q ratio for ground level releases. Therefore, the total on-site dose would be 1.16E-01 mrem.

Table C.9.4.2-2

Loss of CFMT Vent Condenser Cooling - Multipath Dose Summary

Steam Path[1]	DF without HEPA[2] with HEPA	Pounds of Steam Released in 2 Hours	EDE at Site Boundary[3]	
			With HEPAs (mrem)	No HEPAs (rem)
Process Vent to Plant Stack	10^4 10^9	1,000	2.18E-03	0.22
Waste Header/8D-4 to Plant Stack	10^3 10^6	760	1.65	1.65
North Sump/Vitrification Cell HVAC to Vitrification Stack	10^3 10^8	240	4.85E-02	4.85
TOTALS		2,000	1.71	6.72

FOOTNOTES:

1) See Figure C.9.4.2-1 and Text.
2) DF without HEPAs based on boiling partition coefficient of 1E-03 and CFMT demister DF of 10 (applicable to all nuclides except H-3).
3) Based on the ratio of χ/Q values of 2.39, the on-site dose at 640 m from the vitrification stack (ground level) would be 11.6 rem with no HEPA filters. The dose contribution from the plant stack (60 m) at 640 m is negligible under the assumed conditions of 1 m/sec and PGSC F.

Table C.9.4.3-1

Data Summary for SFCM Off-Gas Jumper Failure

Radionuclide	Ci Released to Vitrification Cell	Effective Dose Equivalent - mrem	
		Site Boundary	On-Site (640 m)
Sr-90	3.25E+00	8.8E-03	2.1E-02
Cs-137	2.13E+01	1.4E-03	3.4E-03
Pu-238	4.01E-03	3.8E-03	9.1E-03
Pu-239	7.88E-04	8.3E-04	2.0E-03
Pu-240	5.77E-04	6.1E-04	1.5E-03
Pu-241	3.91E-02	8.8E-04	2.1E-03
Am-241	2.59E-02	2.8E-02	6.7E-02
Cm-244	3.71E-03	2.1E-03	5.0E-03
Totals	4.80E+01	4.6E-02	1.1E-01

TABLE BASES:

- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE).
- Release to the cell is based on Crocker October 10, 1989 mass balance assuming 2 hour discharge at normal SFCM off-gas rate and 13,800 hours total production run time.
- The curie release from the Vit Cell to the environment is through two stage HEPA filtration with a combined DF of 1E+05 for all isotopes.
- The rem/curie conversion factor is based on dose conversion factors from DOE/EH-0070 & 0071, and meteorology of 1 m/sec, PGSC F, and a χ/Q of 6.23E-04 sec/m3 at the site boundary 1050 m NW.
- On-site dose at 640 m is 2.39 times the off-site dose at 1,050 m based on the χ/Q ratio for ground level releases.
- The immediate decay products of Sr-90 and Cs-137, which are included in the rem/Ci conversion factors, double the curies listed for these two isotopes as indicated in the Totals.

Table C.9.4.6-1

Data Summary for HLW Canister Drop

Radionuclide	Ci in Canister	Ci Released to Vitrification Cell	Rem at Site Boundary per Ci Released at Ground Level	EDE at Site Boundary (mrem)
Sr-90	2.39E+04	1.25E-01	2.71E-01	3.4E-04
Cs-137	2.58E+04	1.47E-01	6.69E-03	9.8E-06
Pu-238	2.96E+01	1.54E-04	9.50E+01	1.5E-04
Pu-239	5.82E+00	3.02E-05	1.06E+02	3.2E-05
Pu-240	4.19E+00	2.18E-05	1.06E+02	2.3E-05
Pu-241	2.88E+02	1.49E-03	2.24E+00	3.3E-05
Am-241	1.91E+02	9.92E-04	1.07E+02	1.1E-03
Cm-244	2.73E+01	1.42E-04	5.60E+01	8.0E-05
TOTAL	5.0 E+04	2.7 E-01		1.8 E-03

TABLE BASES:

- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE).
- Release to the cell atmosphere is based on airborne release fraction of 5.2E-06 - see text.
- The curie release from the Vit Cell to the environment is through two stage HEPA filtration with a combined DF of 1E+05 for all isotopes.
- The rem/curie conversion factor is based on dose conversion factors from DOE/EH-0070 & 0071, and meteorology of 1 m/sec, PGSC F, and a χ/Q of 6.23E-04 sec/m3 at the site boundary 1050 m NW.
- On-site dose at 640 m is 2.39 times the off-site dose at 1,050 m based on the χ/Q ratio for ground level releases. Therefore, the total on-site dose would be 4.5E-03 mrem.
- The immediate decay products of Sr-90 and Cs-137, which are included in the rem/Ci conversion factors, would double the curies listed for these two isotopes resulting in a total of 1.0E+05 Ci per canister.

Table C.9.4.7.1-1

Data Summary for Vitrification Process Off-Gas System HEPA Blow-Out

HEPA Filter Loading		Rem at Site Boundary per Ci Released from Main Plant Stack	EDE at Site Boundary (mrem)
Radionuclide	Ci		
Cs-137	8.76E+01	8.06E-04	7.1E+01
Sr-90	8.29E-01	2.93E-02	2.4E+01
Pu-238	1.03E-03	1.03E+01	1.1E+01
Pu-239	2.02E-04	1.14E+01	2.3E+00
Pu-240	1.48E-04	1.14E+01	1.7E+00
Pu-241	1.01E-02	2.24E-01	2.3E+00
Am-241	6.61E-03	1.16E+01	7.7E+01
Cm-244	9.51E-04	6.04E+00	5.7E+00
TOTALS	8.85E+01		2.0E+02

TABLE BASES:

- Filter loading based on the accumulation of the isotopes to the in-cell HEPA filter for the total Vit campaign. The DFs prior to this filter is in accordance with the Mass Balance, Nixon 95, with those curies back calculated to 1990 for the inclusion of other isotopes from Crocker-89.
- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE).
- 1% of HEPA loading is assumed to be released in blow-out, all in respirable range.
- The rem/curie conversion factor is based on dose conversion factors from WVDP-065 for an elevated (60 m) release of 2 hour duration. Maximum χ/Q at site boundary is 6.72E-05 sec/m^3, 1,700 m NE.
- On-site dose at 640 m is negligible because release is from elevated Main Plant stack.
- The immediate decay products of Sr-90 and Cs-137, which are included in the rem/Ci conversion factors, double the curies listed for these two isotopes as indicated in the Totals.

Table C.9.4.7.2-1

Data Summary for Vitrification Cell HVAC System HEPA Blow-Out

HEPA Filter Loading		Effective Dose Equivalent - mrem	
Radionuclide	Ci	On-Site (640 m)	Site Boundary
Cs-137	1.80E+01	2.9E+00	1.2E+00
Sr-90	1.64E+01	1.1E+02	4.4E+01
Pu-238	2.03E-02	4.6E+01	1.9E+01
Pu-239	3.99E-03	1.0E+01	4.2E+00
Pu-240	2.91E-03	7.4E+00	3.1E+00
Pu-241	1.98E-01	1.1E+01	4.4E+00
Am-241	1.31E-01	3.4E+02	1.4E+02
Cm-244	1.88E-02	2.5E+01	1.1E+01
TOTAL	6.82E+01	5.5E+02	2.3E+02

TABLE BASES:

- Filter loading based on assumed releases to cell from slurry spills and SFCM off-gas - see text.
- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE).
- 1% of HEPA filter loading is assumed to be released in blow-out, all in respirable range.
- The rem/curie conversion factor is based on dose conversion factors from DOE/EH-0070 & 0071, and meteorology of 1 m/sec, PGSC F, and a χ/Q of 6.23E-04 sec/m^3.
- On-site dose at 640 m is 2.39 times the off-site dose at 1,050 m based on the χ/Q ratio for ground level releases.
- The immediate decay products of Sr-90 and Cs-137, which are included in the rem/Ci conversion factors, double the curies listed for these two isotopes as indicated in the Total. The curies listed are the combined total loading for two filters.

Table C.9.4.9-1

Data Summary for Loss of Vitrification Facility Power

Radionuclide	Activity Released - Ci		Effective Dose Equivalent - mrem	
	To Vit Cell	To Environment	On-Site (640 m)	Site Boundary
Sr-90	6.50E-01	1.95E-02	12.7	5.3
Cs-137	4.26E+00	1.28E-01	2.1	0.9
Pu-238	8.02E-04	2.41E-05	5.5	2.3
Pu-239	1.58E-04	4.74E-06	1.2	0.5
Pu-240	1.15E-04	3.45E-06	0.9	0.4
Pu-241	7.82E-03	2.35E-04	1.2	0.5
Am-241	5.18E-03	1.55E-04	39.7	16.6
Cm-244	7.42E-04	2.23E-05	3.0	1.2
TOTALS	9.60E+00		66.3	27.7

TABLE BASES:

- Includes all isotopes contributing greater than 1% of the total effective dose equivalent (EDE).
- Release to the cell is equivalent to 0.4 hours of normal SFCM off-gas or 20% of the values listed in column 2 of Table C.9.4.3-1 - see text.
- The curie release from the Vit Cell to the environment is 3% - see text.
- The rem/curie conversion factor is based on dose conversion factors from DOE/EH-0070 & 0071, and meteorology of 1 m/sec, PGSC F, and a χ/Q of 6.23E-04 sec/m3 at the site boundary 1050 m NW.
- On-site dose at 640 m is 2.39 times the off-site dose at 1,050 m based on the χ/Q ratio for ground level releases.
- The immediate decay products of Sr-90 and Cs-137, which are included in the rem/Ci conversion factors, double the curies listed for these two isotopes as indicated in the Totals.

Table C.9.4.11-1

Concentration and Mass of Fissionable Isotopes in Vitrification Process Feed

Isotope	Concentration			Relative Isotopic Distribution[4]
	Vessel[1] (g/L)	Maximum Concentration[2] (g/L)	Critical Limit[3] (g/L)	
U-233	6.69E-4	1.16E-2	10.8	3.95E-4
U-235	3.12E-2	5.43E-1	11.5	1.85E-2
U-238	1.69E+0	2.94E+1	---	1.00E+0
Pu-239	1.87E-2	3.25E-1	7.0	1.11E-2
Pu-240	3.72E-3	6.47E-2	---	2.20E-3
Pu-241	5.07E-4	8.82E-3	---	3.00E-4

1. Concentration based upon mass of solids in vitrification process feed from VITBAL.WKS, Rev.7.
2. Concentration calculated assuming feed solution completely reduced to solids.
3. Critical concentration limits based on values given in NUREG/CR-0095 for a uniform aqueous solution reflected by an effectively infinite thickness of water.
4. Normalized to U-238.

NUREG/CR-0095. Nuclear Safety Guide, TID-7016, Rev. 2. Oak Ridge National Laboratory, June 1978.

Table C.9.5.1-1

Nitric Acid Day Tank Spill Consequences

Meteorological Conditions	Airborne Concentrations Downwind of Ground-Level Release		
	100 m	640 m	1,050 m
D stability, 4.5 m/sec	2.7 ppm	0.14 ppm	0.06 ppm
F stability, 1.0 m/sec	18.6 ppm	0.93 ppm	0.41 ppm

Nitric Acid TEEL Values: TEEL-1: 2 ppm TEEL-2: 15 ppm TEEL-3: 30 ppm

Table C.9.5.2-1

Nitrogen Oxides Release Consequences

Meteorological Conditions	Airborne Concentrations Downwind of Main Plant Stack Release		
	100 m	640 m	1,050 m
D stability, 4.5 m/sec	0 ppm	0.015 ppm	0.023 ppm
F stability, 1.0 m/sec	0 ppm	3.2E-11 ppm	8.4E-06 ppm

NO_x TEEL Values*: TEEL-1: 2 ppm TEEL-2: 15 ppm TEEL-3: 30 ppm

*Nitrogen dioxide TEEL values are shown since they are smaller than nitric oxide TEEL values.

Table C.9.6-1

Radiological Beyond Design Basis Events

Reference SAR Section	Scenario	Bases for Accident	Effective Dose Equivalent		Remarks
			On-Site (640 m)	Site Boundary	
C.9.6.1	BDB Tornado	Not analyzed, but see Section C.9.4.10	N/A	N/A	Frequency < 1E-06/year
C.9.6.2	BDB Earthquake, loss of all power	Direct out-leakage of contaminated cell air following loss of inlet HEPAs	270 mrem	110 mrem	Jumper failure results in escape of SFCM off-gas to cell
	BDB Earthquake, SFCM and CFMT dump	Cell ventilation stops when BDBE causes vessels to fail	3.8 rem	1.6 rem	Cell ventilation systems fails
	BDB Earthquake, SFCM and CFMT dump	Cell ventilation continues after HEPA failure	56.4 rem	23.6 rem	Instrument logic keeps vent system operating after both HEPAs fail, which occurs at t+6 minutes.
	BDB Earthquake, HLWIS roof collapse	Roof falls onto HLW canisters	----	----	No canister failure; roof collapse energy approximately 1/2 that of 7-meter canister drop
	BDB Earthquake Upper Crane falls	Crane falls to rupture 4 canisters	13.6 mrem	5.7 mrem	Crane falls in optimum pattern for canister rupture
C.9.6.3	CFMT steam and slurry release	A break occurs in the CFMT heating coil when the CFMT slurry is at maximum concentration, "atomizing" slurry with steam	2.7 mrem	1.1 mrem	All normal systems operate

Table C.9.6.2.2-1

Beyond Design Basis Accident Data Summary
for CFMT and SFCM Dumps

Maximum Slurry Concentration in CFMT Ci/lb Water[1]		Ci/1,000 ft^3 of Steam[2]	Rem/1,000 ft^3 of Steam Released at Ground Level	
			Site Boundary	On-Site (640 m)
Sr-90	1.45E+01	1.08E+00	2.93E-01	7.00E-01
Cs-137	1.56E+01	1.17E+00	7.82E-03	1.87E-02
Pu-238	1.80E-02	1.34E-03	1.27E-01	3.04E-01
Pu-239	3.53E-03	2.63E-04	2.78E-02	6.64E-02
Pu-240	2.58E-03	1.92E-04	2.03E-02	4.85E-02
Pu-241	1.75E-01	1.31E-02	2.71E-02	6.47E-02
Am-241	1.16E-01	8.64E-03	9.28E-01	2.22E+00
Cm-244	1.66E-02	1.24E-03	6.94E-02	1.66E-01
TOTAL			1.50E+00	3.59E+00

[1] Concentration is based on the reference maximum slurry concentration summarized in Table C.9.4.1-1 and relative distribution of nuclides from Table C.9.4.1-2.

[2] Concentration in steam based on an ARF of 2E-03 (DF of 500).

Table C.9.6.2.2-2

Beyond Design Basis Accident
CFMT or MFHT and SFCM Dumps
Dose From Unfiltered Steam/Water Vapor Releases

Cell Vent System Status	ft^3 of Radioactive Steam Released at Ground Level	Effective Dose Equivalent at Site Boundary (rem)	
		CFMT* Fails	MFHT* Fails
Off At Time Zero	1,060		
Off-Site Dose		1.6	0.4
On-Site Dose		3.8	1.0
Continues to Operate After HEPA Failure	15,700		
Off-Site Dose		23.6	6.2
On-Site Dose		56.4	14.8

* Failure of both CFMT and MFHT results in a dose between the limits tabulated.

Table C.9.6.3-1

CFMT Steam and Slurry Release Failure Frequency

Event	Probability/year
Tank Failure	1E-03
Coil Failure - Same Location	1E-01 to 5E-02
Aspirating Leak Geometry - 10%	1E-01
Fraction of Time at Maximum Concentration - 10%	1E-01
"Poorest" Meteorology - 5%	5E-02
TOTAL	5E-08 to 2.5E-08/year

Table C.9.7-1

Nonradiological Beyond Design Basis Events

Ref/SAR	Scenario	Bases for Accident	Concentration		REMARKS
			On-Site (640 m)	Site Boundary	
C.9.7.1.1	BDB Ammonia Tank Failure	Puncture of Tank	-----	38 ppm	1.0E-04/yr frequency
C.9.7.1.2	BDB Ammonia Accident Failure	Failure of loading hose and excess flow valves fail to actuate	-----	10 ppm	5.2E-06/yr frequency, 50 gpm continuous release
C.9.7.1.3	BDB Ammonia Tank Truck Accident	Not analyzed	N/A	N/A	1.0E-05/yr frequency
C.9.7.2	BDB Nitric Acid Tank Truck Accident	Significant (>10% cargo loss) from truck accident	20 ppm	10 ppm	2.1E-05/yr frequency, evaporation from liquid pool

C.10.0 CONDUCT OF OPERATIONS

The WVDP Conduct of Operations program is presented in detail in Chapter A.10.0 of WVNS-SAR-001, *Project Overview and General Information* (WVNS).

C.10.1 Management, Organization, and Institutional Safety Provisions

C.10.1.1 Organizational Structure

VF-related engineering efforts and operations are headed by the High-Level Waste (HLW) Projects Manager, who reports to the WVNS President. The HLW Systems Engineering Manager, HLW Component Engineering Manager, HLW Tank Closure Manager and Vitrification Operations Manager report directly to the HLW Projects Manager.

The overall WVDP organizational structure is presented in Sections A.10.1 and A.10.2 of WVNS-SAR-001.

C.10.1.2 Organizational Responsibilities

WVDP organizational responsibilities are discussed in Sections A.10.1 through A.10.4 of WVNS-SAR-001.

C.10.1.3 Staffing and Qualifications

WVDP staffing and qualifications are discussed in Section A.10.1 of WVNS-SAR-001.

C.10.1.4 Safety Management Policies and Programs

Safety performance assessment, configuration and document control, event reporting, and safety culture are discussed in Section A.10.4.2 of WVNS-SAR-001.

C.10.2 Procedures and Training

C.10.2.1 Procedures

The development and maintenance of procedures is discussed in Section A.10.4.1 of WVNS-SAR-001.

C.10.2.2 Training

A description of the WVNS training program is presented in Section A.10.3 of WVNS-SAR-001. The training program will be revised in the near future to ensure that fuel handlers are certified in accordance with requirements contained in DOE Order

5480.20A, *Personnel Selection, Qualification and Training Requirements for DOE Nuclear Facilities* (U.S. DOE, November 15, 1994).

C.10.3 Initial Testing, In-Service Surveillance, and Maintenance

C.10.3.1 Initial Testing Program

The *WVDP Components Test Stand (CTS) Conversion to Vitrification Facility Test Program Plan*, WVNS-TPL-63-001, (West Valley Nuclear Services Co., Inc. May 17, 1996) was established as part of the WVDP vitrification program activities to provide focus and emphasis to the transition from construction to operations. The *Test Program Plan* was designed to verify the integrity of the facility, equipment, and process and to substantiate the safety analysis. This was done by conducting and documenting tests designed to prove the equipment, systems, and design before initiating radioactive operations. The pre-operational tests:

- Confirmed that selected design requirements, as identified in the Systems Description test requirements, were met.
- Demonstrated that the various systems operate safely and in an environmentally sound manner.
- Enhanced the training level of the Operations personnel and provided operating experience and data before the introduction of radioactive feed.

The *Plan* covered a phased turnover and graded approach to testing including the precommissioning, commissioning (first operation of equipment), and performance testing (not previously demonstrated) of the systems associated with the vitrification process.

C.10.3.2 In-Service Surveillance and Maintenance Program

A complete description of the WVDP In-Service Surveillance and Maintenance Program is presented in Section A.10.4.3 of WVNS-SAR-001.

C.10.4 Operational Safety

C.10.4.1 Conduct of Operations

The WVDP Conduct of Operations Program is discussed in Section A.10.4.4 of WVNS-SAR-001.

C.10.4.2 Fire Protection

The WVDP Fire Protection Program is discussed in Section A.4.3.6 of WVNS-SAR-001.

C.10.5 Emergency Preparedness Program

The WVDP Emergency Preparedness Program is presented in detail in Section A.10.5 of WVNS-SAR-001.

C.10.6 Decontamination and Decommissioning

Final decontamination and decommissioning (D&D) plans are dependent on facility closure plans which are yet to be determined. Facility design features which will facilitate final D&D have been described in Section C.4.7. Safety analyses and Unreviewed Safety Question Determinations (USQDs) associated with site D&D activities will be performed as appropriate.

The WVDP Decommissioning Program is also discussed in Section A.10.6 of WVNS-SAR-001.

REFERENCES FOR CHAPTER C.10.0

U.S. Department of Energy. November 15, 1994. DOE Order 5480.20A, *Personnel Selection, Qualification and Training Requirements for DOE Nuclear Facilities.*

West Valley Nuclear Services Co., Inc. Safety Analysis Report WVNS-SAR-001: *Project Overview and General Information.* (Latest Revision.)

______________. WVNS-TPL-63-001, WVDP Components Test Stand (CTS) Conversion to Vitrification Facility Test Program Plan.

C.11.0 DERIVATION OF TECHNICAL SAFETY REQUIREMENTS

C.11.1 Introduction

The objective of this chapter is to provide information that satisfies the requirements of Topic 16 of DOE Order 5480.23, *Nuclear Safety Analysis Reports*, which relates to the derivation of Technical Safety Requirements (TSRs) (U.S. Department of Energy April 30, 1992). This chapter is normally used to link the accident analyses, through descriptions of the safety-related structures, systems, and components (SSCs), to the TSR document of a given facility. The TSR document, as stated in DOE Order 5480.22, *Technical Safety Requirements*, is intended to constitute an agreement or contract between the U.S. Department of Energy (DOE) and the applicable managing and operating (M&O) contractor (in this instance West Valley Nuclear Services, Inc. [WVNS]) regarding the safe operation of a given facility, activity, or operation (U.S. Department of Energy February 25, 1992).

As stated in DOE Order 5480.22, the DOE's "first safety responsibility must be the protection of the public." This is also the first safety responsibility of WVNS. Those who work at the West Valley Demonstration Project (WVDP) accept some risk of exposure to radioactive and other hazardous materials due to the nature of the materials with which the WVDP facilities operate. Nevertheless, it is incumbent upon the DOE and WVNS to ensure that WVDP facilities are operated in a manner that minimizes the risk to workers and limits exposures to hazardous materials to levels permitted by federal or state regulations and relevant DOE Orders and Notices.

C.11.2 Requirements

This Final Safety Analysis Report (FSAR) meets the requirements in DOE Order 5480.23 and DOE Order 5480.22 with respect to TSRs. The guidance contained in DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, has also been considered in this regard.

C.11.3 Technical Safety Requirement Considerations

DOE-STD-3009-94 defines safety class SSCs as follows: "Systems, structures, or components including primary environmental monitors and portions of process systems, whose failure could adversely affect the environment, or safety and health of the public as identified by safety analyses. For the purposes of implementing this Standard, the phrase (adversely affect) means Evaluation Guidelines are exceeded. Safety class SSCs are systems, structures, or components whose preventive or mitigative function is necessary to keep hazardous material exposure to the public below the off-site Evaluation Guidelines. This definition would typically exclude items such as primary environmental monitors and most process equipment" (U.S.

Department of Energy July 1994). The Evaluation Guidelines for the Vitrification Facility (VF) are provided in Chapter 9 of this FSAR.

There are no Evaluation Basis Accidents (EBAs) analyzed in Chapter 9 of this FSAR that have consequences associated with them that exceed the Evaluation Guidelines provided in Chapter 9. The consequence analyses developed for comparison with Evaluation Guidelines only took credit for passive confinement barriers such as the Vitrification Cell, Transfer Tunnel, and Crane Maintenance Room roof, walls, hatches, and shield windows. These analyses did not take credit for High-Efficiency Particulate Air (HEPA) filtration of releases. Therefore, it can be stated that (1) There are no EBAs that require active safety class SSCs to ensure consequences to receptors are below Evaluation Guidelines and (2) There are no SSCs under the direct control of the VF operators that are used to mitigate the consequences to receptors such that the consequences are below Evaluation Guidelines. Hence, consistent with the definition of a safety class SSC provided in DOE-STD-3009-94, no active SSCs associated with the VF have been designated as safety class.

In its discussion of worker safety, DOE Order 5480.22 states "The protection of the health and safety of workers is assured by the combination of: (1) The development of TSRs for barriers to uncontrolled releases and for preventive and mitigative systems, components, and equipment; (2) Use of PPE; (3) Emergency protection programs; (4) Worker education; and (5) Drills." Of these five items, only one is specifically addressed in TSRs, namely "barriers to uncontrolled releases and for preventive and mitigative systems, components, and equipment." Relative to barriers for protection of the public and co-located WVDP workers, no active VF SSCs have been designated as safety class for reasons stated in the previous paragraph.

Barriers for VF worker protection constitute one of the (if not the) primary contributor to defense in depth. Chapter 8 of this FSAR contains a significant discussion of defense in depth as it pertains to the VF. DOE-STD-3009-94 states that SSCs that are "major contributors to defense in depth are designated as safety-significant SSCs" and "Estimates of worker consequences for the purpose of safety-significant SSC designation are not intended to require detailed analytical modeling. Considerations should be based on engineering judgment of possible effects and the potential added value of safety-significant SSC designation." Based on "engineering judgment of possible effects and the potential added value of safety-significant SSC designation," no VF SSCs have been designated as safety-significant SSCs (even though they may contribute to defense in depth).

A review of that portion of the EBA consequence assessments, provided in Chapter 9, that are intended to portray risk (i.e., realistically expected outcomes) as opposed to "worst plausible scenario" for comparison to Evaluation Guidelines, reveals that the VF, even under accident conditions, is a relatively benign facility in terms of potential health and safety impacts to on-site and off-site receptors. For example, the Chapter 9 accident analyses indicate that several key systems (i.e., Power, Process Off-Gas, and HVAC) can be lost simultaneously with essentially negligible consequences. It is noted that this scenario is modeled very conservatively (i.e., modeled so as to lead to larger doses than are likely to be received), and prompt initiation of radiological surveys, installation of portable Continuous Air Monitors (CAMs), and appropriate emergency response (such as reducing Vitrification Building staffing to essential personnel and wearing anti-C clothing and respirators if prudent or necessary) would minimize the radiological impact. Additionally, since the radiological and hazardous materials in the Vitrification Cell are enclosed/confined by the in-cell process systems and components, the more likely scenario is that the Vitrification Building operating aisles would not become significantly contaminated, if at all.

In general, it can be stated that the VF is benign in terms of potential health and safety impacts if (1) One or more of the in-cell or ex-cell HEPA filters associated with the Process Off-Gas system and Vitrification Cell HVAC system remain functional (assuming that the ex-cell flowpaths are not breached), and (2) The passive confinement barriers such as the Vitrification Cell, Transfer Tunnel, and Crane Maintenance Room roof, walls, hatches, and shield windows maintain their structural integrity.

Since no VF SSCs that are active or under an operator's direct control have been designated as safety class or safety-significant based on DOE-STD-3009-94 guidance and the rationale presented above, no safety limits, operating limits (including limiting control settings and limiting conditions for operation), and surveillance requirements, as described in DOE Order 5480.22, are established for the VF.

C.11.3.1 Administrative Controls

DOE Order 5480.22 states that Administrative Controls are "the provisions \relating to organization and management, procedures, recordkeeping, reviews, and audits necessary to ensure safe operation of the facility." The subject Order elaborates on these topics and the importance of select programs to ensure safe and healthful operation of a given facility. In discussing Administrative Controls (in the section that addresses the preparation of TSRs), DOE Order 5480.22 states "This section should impose administrative requirements necessary to control operation of the facility such that it meets the TSR." As used in this context, TSR is evidently referring to everything TSRs shall consist of except "Administrative Controls". (Pages 10, 11, and 12 of DOE Order 5480.22 clearly state that TSRs shall consist of the following: use and application, safety limits, operating limits [including limiting control settings and limiting conditions for operation], surveillance requirements, administrative controls, and appendices that include information on basis and design features.) For reasons previously stated, there are no safety limits, operating limits, or surveillance requirements associated with the VF. Hence, there are no TSRs to meet that require Administrative Controls.

WVDP workers accept some risk beyond that accepted by the public because of the necessary and inherent presence of hazardous and radioactive materials at WVDP facilities and the workers' proximity to these materials. TSRs are not based on maintaining worker exposures below some acceptable level following an uncontrolled release of radioactive and/or hazardous material or inadvertent criticality; rather, the risk to workers is reduced through the reduction of the likelihood and potential impact of such events. It is impractical to attempt to reduce worker risk to an insignificant level through TSRs. In its discussion of worker safety, DOE Order 5480.22 acknowledges that "The impact from the release of hazardous materials is also reduced through industrial hygiene and radiation protection oversight (e.g., monitoring of worker exposures, use of personnel protective equipment [PPE] and emergency evacuation planning), as well as the use of TSRs." This statement indicates that formal measures other than TSRs are recognized by the DOE as being acceptable for ensuring worker safety. DOE-STD-3009-94 reinforces this position, stating: "It is important to develop TSRs judiciously. TSRs should not be used as a vehicle to cover the many procedural and programmatic controls inherent in any operation." Consistent with relevant DOE Orders and federal and state regulations with which WVNS is currently contractually obligated to comply, the control of the levels of hazardous and radioactive materials to which workers may, at any time, be exposed, is addressed in WVDP radiological protection and occupational safety and health programs. Furthermore, worker exposure to hazardous materials and/or conditions is regulated under the provisions of the Occupational Safety and Health Act administered by the Occupational Safety and Health Administration (OSHA).

C.11.3.2 Summary Regarding TSRs for the Vitrification Facility

DOE Order 5480.22 and DOE-STD-3009-94 both indicate that, with the exception of safety class SSCs, there is significant latitude as to the content of a given facility's TSRs. This is consistent with the statement in DOE Order 5480.22 that "DOE's first safety responsibility must be the protection of the public." This latitude, in conjunction with the specifics discussed above and existing contractual health and safety related commitments that the incumbent WVDP M&O contractor has to the DOE, provide adequate justification for there not being TSRs (i.e., safety limits, operating limits, surveillance requirements, and administrative controls per DOE Order 5480.22) associated with the VF.

C.11.4 Interface with TSRs from Other Facilities

There are no TSRs from other facilities that interface with the VF.

REFERENCES FOR CHAPTER C.11.0

U.S. Department of Energy. February 25, 1992. Change 2 (January 23, 1996). DOE Order 5480.22: *Technical Safety Requirements*. Washington, D.C.: U.S. Department of Energy.

______________. April 30, 1992. Change 1 (March 10, 1994). DOE Order 5480.23: *Nuclear Safety Analysis Reports*. Washington, D.C.: U.S. Department of Energy.

______________. July 1994. DOE STD-3009-94: *Preparation Guide for U.S. Department Of Energy Nonreactor Nuclear Facility Safety Analysis Reports*. Washington, D.C.: U.S. Department of Energy.

C.12.0 QUALITY ASSURANCE

C.12.1 Introduction

The West Valley Demonstration Project's (WVDP's) Quality Assurance Program (QAP) is implemented on a site-wide basis. The WVDP QAP complies with 10 CFR 830.120, *Quality Assurance Requirements*. The document hierarchy for support of the QAP is given in WVDP-111, *Quality Assurance Program*. Requirements identified by WVDP-111 are implemented by policies and procedures contained in WVDP-002, *Quality Management Manual,* and selected procedures in WVDP-117, *WVNS Policies and Procedures Manual*. An extensive description of the Quality Assurance Program is provided in Chapter A.12.0 of WVNS-SAR-001.

WVDP-074, *WVNS Quality Assurance Program for WVDP High Level Waste Form Production Through Acceptance* and WVDP-212, *West Valley Area Office Quality Assurance Program Description for WVDP High Level Waste Form Production Through Acceptance,* were prepared and implemented to be consistent with the requirements of the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (DOE-RW), *Quality Assurance Requirements and Description*, DOE/RW-0333P, Rev. 0 (U.S. Department of Energy December 18, 1992). These documents, which describe the QAP for high-level radioactive waste acceptance process and production activities at the WVDP, also describe the QAP as implemented at the OH, the OH/WVDP, and the WVNS M&O contractor level. These documents use DOE/RW-0333P as their foundation document, which is primarily based upon ASME-NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, (American Society of Mechanical Engineers September 1989).

C.12.2 Management and Organization

Section A.12.1 of WVNS-SAR-001 describes the organizational structures, functional responsibilities, levels of authority, and communication lines for quality issues at WVNS. WVNS has the overall responsibility for quality assurance during design, procurement, construction, installation, modifications, testing, and operation of the Vitrification Facility (VF).

Although the overall responsibility for the WVDP QAP is retained by the DOE Office of Environmental Restoration and Waste Management (DOE-EM), the responsibility for establishing and implementing the WVDP QAP is shared by the unique producer organizations. Final responsibility for the overall QAP, as applicable to the quality and acceptability of the canistered waste form, is retained by the DOE-RW. The document control and distribution requirements for WVDP-074 and WVDP-212 are the responsibility of WVNS.

The overall QAP is directed and administered by DOE-EM with more detailed accountability at the performing level of Vitrification Project activities. Direct

Project management and communications authority and responsibility, including quality assurance, for DOE-EM has been assigned to the EM-37, High-Level Waste Division. EM-37 provides direct DOE-EM management, direction, and communication to and through the OH/WVDP. This arrangement facilitates efficient conduct of the Project activities thus eliminating redundant implementation of elements and allowing higher levels of Project management to focus on verification and overview. The WVDP High-Level Waste organizational structure is summarized in Figure C.12.2-1. WVDP high-level waste quality assurance requirements are shown in Figure C.12.2-2.

Section A.1.4 of WVNS-SAR-001 identifies the agents and contractors responsible for implementing the West Valley Demonstration Project Act (Public Law 96-368 [U.S. Congress October 1, 1980]). The relationships between WVNS and its agents and contractors is illustrated in Figure A.1.4-1 of WVNS-SAR-001. The major program participants for the high-level waste QAP implementation are given in Figure C.12.2-3.

C.12.3 Performance

Section A.12.2 of WVNS-SAR-001 discusses the QAP Plan, while Section A.12.3 of WVNS-SAR-001 describes the quality levels used by WVNS to implement the QAP. The QAP Plan described in WVNS-SAR-001 addresses design control; procurement document control; instructions, procedures, and drawings; control and identification of purchased material, equipment, and services, including the control of work processes; inspection, surveillance and testing; nonconforming items; corrective action; and quality assurance records and audits. These measures aid in ensuring that performed work meets all applicable requirements.

Items essential to certification and acceptance of the canistered waste form are identified in WVDP-200, *Waste Acceptance Manual*. In addition, WVDP-200 defines the scope of the application of the high-level waste QAP. The quality levels and safety classes of VF structures, systems, and components are listed in WVDP-204, *WVDP Quality List "Q-List"*.

C.12.4 Assessment

Assessment and audit activities are discussed in Chapter A.12.0 of WVNS-SAR-001. OH/WVDP periodically reviews the program management of WVNS and the major Project participants to ensure adequacy and compliance with contractual requirements.

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