DRAFT SAFETY EVALUATION REPORT ON THE VITRIFICATION PROCESS AND HIGH-LEVEL WASTE INTERIM STORAGE

REVIEW OF WVNS-SAR-003, REVISION 2, DRAFT D

Prepared for

Nuclear Regulatory Commission
Contract NRC-02-93-005

Prepared by

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

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PREVIOUS REPORTS IN SERIES

Number	Name	Date Issued
CNWRA 91-015	"Safety Evaluation Report on the West Valley Demonstration Project Supernatant Treatment System" Safety Analysis, Volume III (WVNS-SAR-004, Rev. 6)	November 1991
CNWRA 93-007	Seismic/Tornado Analysis Review for the Vitrification Facility at West Valley	April 1993
CNWRA 93-008	Review of Corrosion Aspects of High-Level Waste Storage Tanks at West Valley	April 1993
Letter Report	Review of the West Valley THOREX Waste Neutralization Process	September 1994

ABSTRACT

This safety evaluation report (SER) reviews the radiological safety aspects of design and operation of the Vitrification Process (VP) and High-Level Waste Interim Storage (HLWIS) at the West Valley Demonstration Project (WVDP) in West Valley, New York, as documented in the Safety Analysis Report WVNS-SAR-003, Revision 2, Draft D. The VP is being undertaken to transform the liquid inventory of radioactive high-level waste into a more stable and less hazardous waste form—canistered borosilicate glass.

The SER provides background information on the WVDP facilities with respect to modifications made for the VP and HLWIS. Radiological hazards are discussed, and those factors governing design are identified as seismic loads and tornadoes and tornado-generated missiles, for most radiologically important structures, systems, and components. The design philosophy at the WVDP is reviewed as it relates to multiple barriers for control of radiological contamination, use of ventilation zones for direction of airborne contamination away from occupied areas, defense-in-depth, and as-low-as-is-reasonably-achievable (ALARA). Individual systems and components within the scope of WVNS-SAR-003 are reviewed with respect to margins of safety and incorporation of key design concepts. Radiological doses for normal operations, design basis events, and beyond design basis events are reviewed with respect to WVDP evaluation guidelines and NRC-established permissible levels. Administrative features of VP operations and programmatic considerations are also reviewed. Conclusions from the review indicate that no comments remain open that are critical to the safe operation of the facility.

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ACRONYMS AND ABBREVIATIONS

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ALARA	As Low As is Reasonably Achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
BDBA	Beyond Design Basis Accident
BDBE	Beyond Design Basis Earthquake
CC	Chilled Water System
CCB	Cold Chemical Building
CCS	Cold Chemical System
CFMT	Concentrator Feed Make-up Tank
CMR	Crane Maintenance Room
CNWRA	Center for Nuclear Waste Regulatory Analyses
CPC	Chemical Process Cell
CR	Control Room
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBT	Design Basis Tornado
DF	Decontamination Factor
DGR	Diesel Generator Room
DOE	U.S. Department of Energy
DOP	Dioctyl Phthalate
EBA	Evaluation Basis Accident
EDE	Effective Dose Equivalent
EDR	Equipment Decontamination Room
EG	Evaluation Guideline
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FACTS	Functional and Checkout Testing of Systems
FCSS	Division of Fuel Cycle Safety and Safeguards
FEA	Finite Element Analysis
FMEA	Failure Modes and Effects Analysis
GTAW	Gas Tungsten Arc Welding
HEME	High Efficiency Mist Eliminator
HEPA	High Efficiency Particulate Air Filter
HLW	High-level Radioactive Waste
HLWIS	High-level Waste Interim Storage
HLWTS	High-level Radioactive Waste Transfer System
HOTP	Hot Operations Test Plan
HVAC	Heating, Ventilation, and Air Conditioning
ILDS	Infrared Level Detection System
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratories
LLW	Low-Level Radioactive Waste

ACRONYMS AND ABBREVIATIONS (cont'd)

LWTS	Liquid Waste Treatment System
MFHT	Melter Feed Hold Tank
MOU	Memorandum of Understanding
NFPA	National Fire Protection Association
NFS	Nuclear Fuel Services
NMSS	Office of Nuclear Material Safety and Safeguards
NOX	Oxides of Nitrogen (Nitric or Nitrous)
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NYSERDA	New York State Energy Research and Development Authority
OBE	Operations Based Earthquake
PGA	Peak Ground Acceleration
PHA	Process Hazard Analysis
PSD	Power Spectral Density
psig	Pounds per Square Inch Gauge
PSV	Pseudovelocity
PUREX	Plutonium-Uranium Recovery Extraction
PVS	Plant Ventilation System
QA	Quality Assurance
RG	Regulatory Guide
SAR	Safety Analysis Report
SBS	Submerged Bed Scrubber
SCR	Selective Catalytic Reduction
SER	Safety Evaluation Report
SFCM	Slurry-Fed Ceramic Melter
SFR	Secondary Filter Room
SHA	Seismic Hazards Analysis
SIP	Special Instruction Procedure
SOP	Standard Operating Procedure
SS	Stainless Steel
SSE	Safe Shutdown Earthquake
TEDE	Total Effective Dose Equivalent
THOREX	Thorium Recovery Extraction
TIP	Test Instruction Procedure
TRU	Transuranic Waste
TSD	Technical Support Document
UBC	Uniform Building Code
UPS	Uninterruptible Power Supply
VB	Vitrification Building
VC	Vitrification Cell
VF	Vitrification Facility
VP	Vitrification Process
WTFVS	Waste Tank Farm Ventilation System
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services Co., Inc.

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QUALITY OF DATA

DATA: Sources of data are referenced in each chapter. The respective sources of these data should be consulted for determining their levels of quality assurance.

EXECUTIVE SUMMARY

The Safety Evaluation Report (SER) presented in this document reflects a detailed review and analysis of the WVNS-SAR-003, Safety Analysis Report (SAR) for Vitrification System Operations and High-Level Waste Interim Storage (HLWIS). As a precursor to this report, the Nuclear Regulatory Commission (NRC) and their contractor, the Center for Nuclear Waste Regulatory Analyses (CNWRA), participated in the review of an earlier version of this SAR and provided the U.S. Department of Energy (DOE) and their principal contractor, West Valley Nuclear Services Co., Inc. (WVNS), questions and comments on the substance and presentation of the material in that SAR (Rowland, 1995).

The NRC review is based on identifying Concerns, Questions, and Comments on radiological safety issues. As a result of the review of the earlier version of the WVNS-SAR-003 (Draft C), there were no topics or items that were categorized as Concerns. As part of the review process, the NRC/CNWRA reviewers had the opportunity to visit the site, visually examine the as-built Vitrification Facility (VF) systems, and components and discuss the structural and radiation safety issues with the WVNS design and plant personnel. The site visits provided insights into the VF design and operations that were not clear from reviewing the earlier version of the SAR. The NRC provided the DOE with detailed Questions and Comments to clarify issues not evident in the SAR (Draft C). As a result of the interactions with the DOE and WVNS, the NRC Questions were responded to in oral and written presentations (Rowland, 1995). The current version of the WVNS-SAR-003 (Draft D) has addressed all the NRC Questions and many of the NRC Comments.

With the background described above, the focus of this review of the WVNS-SAR-003 (Draft D) is to develop any additional comments and recommendations for the safe future operations of the VF. The SER provides a comprehensive review of the material presented in the WVNS-SAR-003 and develops evaluation statements on the basis of current NRC regulations and established engineering practice wherever possible. It should be noted that the WVNS-SAR-003 addresses nonradiological issues as well. However, the SER does not provide any review of nonradiological issues as they are outside the regulatory interest and authority of the NRC.

The summary of the conclusions drawn from the review of the SAR for the safe operations of the VF is provided below:

- The design approach, one that emphasizes multiple barriers of confinement, for the VF reflects good engineering practice and is based on methodology used historically for facilities with similar or greater hazards.

- Passive confinement barriers maintain doses and releases at acceptable levels during accident conditions.

- Active confinement barriers maintain doses and releases at very low levels during normal operations, and their function is needed to ensure that cumulative effects of radiological releases are below acceptable levels.

- The solid waste form produced by the Vitrification Process (VP) inherently minimizes potential releases due to accidents involving filled high-level radioactive waste (HLW) canisters.

- The normal operational and severe environmental loads defined for the VF conform with standard engineering practice. The parameters associated with the design basis earthquake (DBE), design basis tornado (DBT), and tornado-generated missiles are in conformance with standard engineering practice as modified for site-specific conditions.

- The basic procedures used in the seismic and tornado design and analysis of the individual components and equipment were in accordance with standard engineering practice at the time of design. The re-evaluation of seismic response of structures is based on current codes and standards.

- The population of structures, systems, and components considered for seismic loading in the WVNS-SAR-003 includes most of those that are important to active and passive confinement.

- The major structural elements of the confinement barriers, including the roof, wall, and mat, have acceptable margins of safety.

- The special doors, windows, hatches, and penetrations have margins of safety that are acceptable for both the DBE and DBT. Reasonable assumptions have been used in calculating the consequences of tornado missiles striking the Vitrification Cell (VC) windows. Although failure of one of the windows is possible due to the missile impact, the probability of occurrence is remote, and the releases are below acceptable levels.

- Margins of safety for other structures, systems, and components indicate that no component or structure analyzed will fail when subjected to the DBE.

- The Process Hazard Analysis (PHA) conducted for the VP is adequate for identifying key hazards and representing the consequences. The protection and mitigating systems associated with the hazards are found to be reasonable based on the review of the in-cell design features and the operational constraints presented in WVNS-SAR-003.

- Future revisions of WVNS-SAR-003 should include a discussion on tests for functionality of leak detectors in pump pits and those in the transfer trench.

- Future revisions of WVNS-SAR-003 should include discussions on safety aspects of Pump Pits 8Q-1 and 8Q-4 and the buried double-walled steel pipe from these two pits.

- The calculated annual releases from airborne and liquid wastes at the site boundary resulting from normal operations are acceptable. The principal criteria used for on-site radiation control will limit the worker annual dose to acceptable levels.

- The list of evaluation basis accidents (EBAs) and events analyzed is appropriate and covers a broad spectrum. The assumptions and parametric values used in the calculations are conservative and, in many cases, bounding.

- The calculated off-site and on-site doses due to beyond design basis accidents (BDBAs) are below Evaluation Guideline (EG) levels and are acceptable. The conservatism used in the

assumptions made in the calculations provide added assurance for the radiological safety of the operations of the VF.

- For the man-made accidents in the anticipated and unlikely accident categories, the 10 CFR Part 20 and 10 CFR Part 100 dose rates are appropriate and are used in the EGs.

- The risks associated with not executing important administrative procedures or controls during the vitrification operations need to be assessed to ensure proper training for the staff.

- Estimates of the quantities of waste [such as spent high-efficiency particulate air filters (HEPA) from the off-gas and heating, ventilation, and air conditioning (HVAC) systems] need to be addressed in the WVNS-SAR-003 to ensure the adequacy of the storage and handling capacity for solid and liquid wastes generated during the period of vitrification.

- The potential concentration of fissile material by chemical, thermodynamical, and mechanical means was shown to be remote.

- Materials with corrosion resistance or with adequate thickness for corrosion allowance have been used in the design of structural components.

WVNS-SAR-003 addresses all Concerns (Rowland, 1995) with respect to operation of the VF and HLWIS facility. Throughout the review process, Questions and Comments (Rowland, 1995) arose concerning specific issues that have, in part, been addressed in Revision D of WVNS-SAR-003. CNWRA reviewers conclude that Questions and Comments remaining open are not critical to the safe operation of the facility.

1 INTRODUCTION

1.1 PURPOSE

This Safety Evaluation Report (SER) was developed to provide an assessment of radiological safety issues associated with the planned Vitrification Process (VP) activities at the West Valley Demonstration Project (WVDP), West Valley, New York. The SER is based on the Safety Analysis Report (SAR) for Vitrification System Operations and High-Level Waste Interim Storage (HLWIS), WVNS-SAR-003, Revision 2, Draft D (West Valley Nuclear Services Co., Inc., 1994a), prepared by the West Valley Nuclear Services (WVNS) Company for the U.S. Department of Energy (DOE).

The WVDP was established by the WVDP Act of October 1, 1980 (Public Law 96-368). The Act directs the DOE to conduct five major activities as part of the WVDP. They include:

- Solidify the liquid high-level radioactive waste (HLW) stored at the site
- Develop containers for the solidified HLW
- Transport the waste to a federal repository for disposal
- Dispose of low-level waste (LLW) and transuranic (TRU) waste produced by the project
- Decontaminate and decommission the facilities

The WVDP Act provides for an oversight function for the Nuclear Regulatory Commission (NRC) to ensure that there is no significant risk to public radiological health and safety. The review and consultation with the NRC will be on an informal basis and will not require formal procedures or action by the NRC. Specifically, the Act requires the NRC to support the following activities:

- Review and comment on the DOE plan for the solidification of HLW, the removal of the waste for the purpose of solidification, the preparation of the waste for disposal, and the decontamination of the facilities to be used in solidifying the waste
- Provide consultation on the wasteform and the containers to be used in the permanent disposal of the solidified waste
- Review SARs and other information prepared by the DOE for identifying any danger to the public health and safety
- Monitor the activities under the project to assure public radiological health and safety

Pursuant to the requirements of the WVDP Act, a Memorandum of Understanding (MOU) between the NRC and the DOE was issued in 1981. The MOU provides the details of how the NRC will fulfill its responsibilities under the Act.

The NRC provides the oversight function, primarily by preparing SERs for the DOE SARs and participating in technical review meetings. The NRC is also involved in monitoring selected testing

conducted at the WVDP and observing DOE quality assurance (QA) audits at the site. CNWRA staff have also provided support to the NRC during DOE QA audits.

With regard to the WVNS-SAR-003, the NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) participated in the review of earlier drafts of the WVNS-SAR-003 with a team comprised of the DOE-instituted Technical Review Board and other groups within the DOE. As a result of these review meetings, several comments and issues raised during the meeting relating to the WVNS-SAR-003 were discussed, and some were resolved. A large number of the comments were of a nonradiological nature. The evaluation presented here does not address issues that do not have a bearing on radiological safety.

1.2 BACKGROUND/HISTORY OF THE FACILITY

The operations of the WVDP are conducted within the Western New York Nuclear Services Center. The Center, located about 35 miles south of Buffalo, New York, is owned by the State of New York. The state agency responsible for administering the site is the New York State Energy Research and Development Authority (NYSERDA). Between 1966 and 1972, Nuclear Fuel Services (NFS), under an NRC license, operated a spent-fuel reprocessing plant at the Center. During this period, the plant reprocessed light-water reactor spent fuel as well as spent fuel from the Hanford N-Reactor. A limited quantity of thorium-bearing fuel was also reprocessed. The plant did not operate between 1972 and 1982. In 1982, as a result of the West Valley Act of 1980, the DOE assumed control of the site from NFS. Since that time, the site has been operated under contract to the DOE by the WVNS Company, a wholly owned subsidiary of the Westinghouse Electric Corporation.

The 6 yr (1966–1972) of reprocessing operations produced approximately 2.2 million liters of HLW. The waste was stored in two separate tanks below ground level. The Plutonium-Uranium Recovery Extraction (PUREX) process waste, which is alkaline in nature, was stored in a large carbon steel tank, 8D-2, and was approximately 2.1 million liters in volume. The acidic waste from the Thorium Recovery Extraction (THOREX) process was stored in a smaller stainless steel tank, 8D-4. The THOREX waste was about 31,000 liters. The THOREX waste, being acidic, remained in a single liquid phase, while the PUREX waste had both a liquid and a semi-solid or sludge phase.

To date, the WVDP has completed several activities. Besides maintaining the tank farm and existing facilities, most of the supernatant (liquid phase) in Tank 8D-2 has been processed through the liquid waste treatment system (LWTS) and converted to low-level cement wastes. A single sludge wash cycle of the remaining waste in 8D-2 has been completed. The THOREX waste from Tank 8D-4 was transferred and neutralized with the contents in Tank 8D-2. The supernatant from the combined sludge wash was treated as part of the low level waste treatment system. Tank 8D-2 will also receive the ground-up zeolite and titanium-coated zeolite ion exchange media used in exchange columns primarily to remove cesium from the liquid wastes from Tank 8D-1. Once all the sludge washing cycles are completed, the HLW will be used as a slurry feed for the vitrification (solidification) process. The method of solidification chosen for the West Valley HLW is a VP using a slurry-fed ceramic melter. During the construction stage, the melter has been used for conducting nonradioactive vitrification tests.

The approach taken by WVNS during the period of pretreatment of the HLW was to issue SARs for each process of the project. However, with the impending vitrification activities, WVNS is concentrating on three SARs. WVNS-SAR-001 (West Valley Nuclear Services Co., Inc., 1993) deals with

the description of all the existing facilities at the Center and the site characteristics. WVNS-SAR-002 (West Valley Nuclear Services Co., Inc., 1994b) addresses all the systems and processes that are necessary to support the start of the vitrification activity. Currently, both WVNS-SAR-001 and WVNS-SAR-002 are undergoing changes. WVNS-SAR-003, the subject of this report, deals with all aspects of the VP and HLWIS. The DOE and the WVNS expect the SARs to be living documents, meaning that they will be periodically upgraded or otherwise modified.

The periodic updating of the SARs does not, in itself, pose a problem. However, there are instances when one SAR refers to another SAR for certain information, and the information does not specifically appear in the cited SAR because it is under revision. The timing and the revision status of the SARs should be made clear to avoid confusion.

1.3 DESCRIPTION OF THE VITRIFICATION FACILITY

Based on the definition given in Table I of LA-10294-MS (Elder et al., 1986), the West Valley Facility can be classified under the following definitions:

Facility Type	Waste Processing and Storage
Operations	Convert liquid waste to solid state, treat, and dispose of waste
Radionuclides	High- and low-level liquid and solid wastes; fission products and actinides
Relative Source Term	Low to Intermediate
Dispersion Potential	Fire in ex-cell areas, especially in Building 01-14
Principal Design Basis Accident (DBA)	Fire; material release by leaks, mishandling, or container failure

There are several functions to be performed during the process of vitrification of HLW. In the sequence of the process steps, these functions include: transfer of sludge to the vitrification cell (VC); preparation of nonradioactive chemicals; concentration of the mix of the sludge and chemicals; transfer of feed to the melter via a holding tank; transfer of molten material to containers; closure and decontamination of filled containers; transfer of waste containers to interim storage; collection and treatment of off-gases before any release; operation of the Heating, Ventilation, and Air Conditioning (HVAC) system; and monitoring of releases at the stack.

The process steps covered under the WVNS-SAR-003 are shown schematically in Figure 1-1. The various components that carry out the VP are housed in different areas or buildings. Collectively, they are described as the Vitrification Facility (VF). The VF includes: the Transfer Trench, Vitrification Building (VB), Cold Chemical Building (CCB), 01-14 Building, Transfer Tunnel, Load-In/Load-Out Area, Equipment Decontamination Room (EDR), HLWIS, Off-Gas Trench, and Diesel Fuel Oil Storage Tank Building. The major components associated with the process identified in Figure 1-1 are described below:

1. Tank Farm—Existing tanks with HLW. Tank 8D-2 is the origin of the waste stream. The tanks are not considered as part of the WVNS-SAR-003.

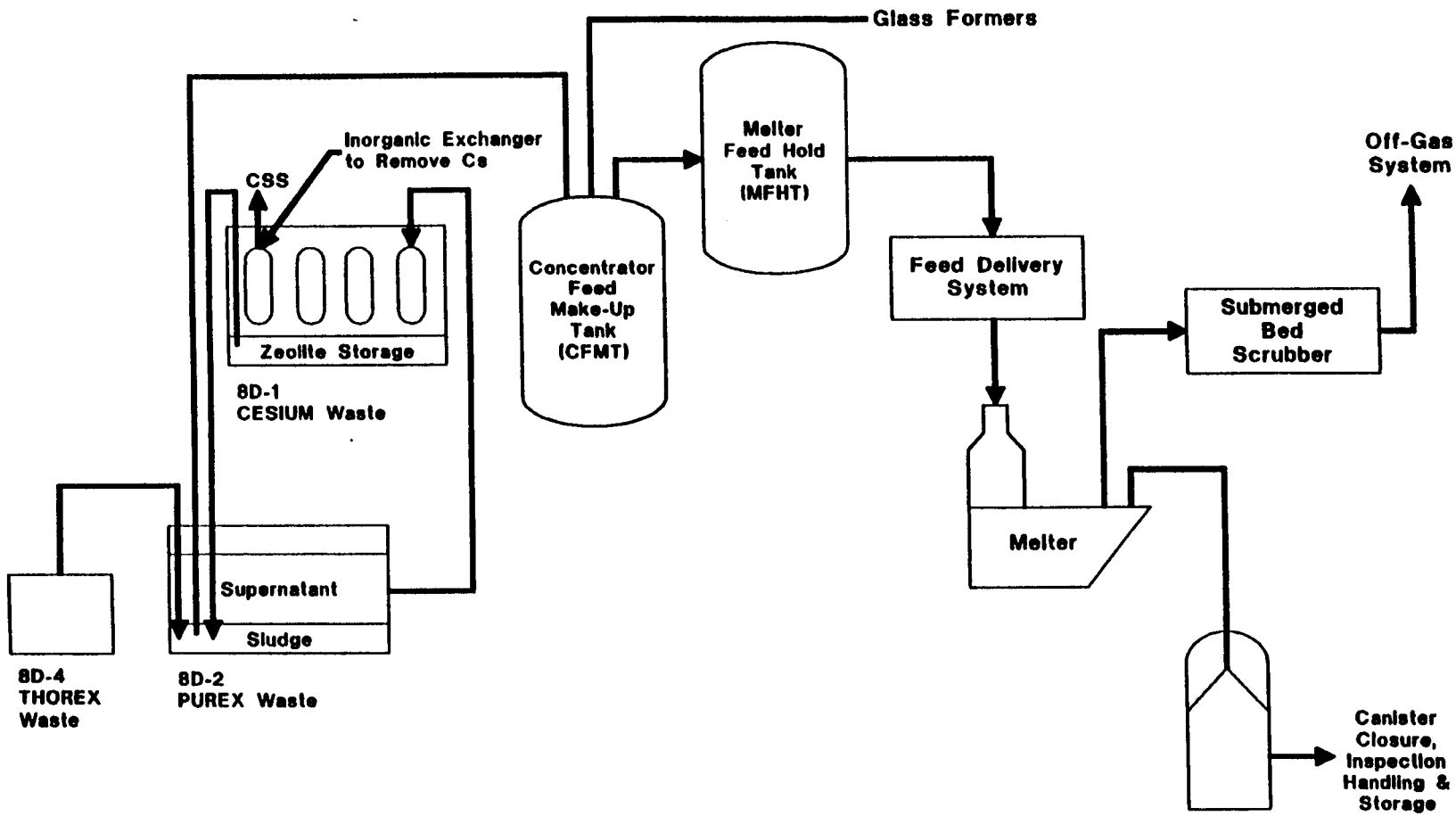


Figure 1-1. Vitrification facility flow diagram (WVNS-SAR-003, Rev. 2, Draft D, Fig. C.6-1)

2. Pump Pits—These are areas near the tanks that provide access to the tanks, and they contain valves, jumpers, drains to the tanks, and capability of ventilation during maintenance. These pits facilitate transfer and control the flow direction of the mobilized sludge.

3. HLW Transfer Pipes and Trench—Double-walled 304L stainless steel (SS) piping in covered concrete trenches provide the transportation for the sludge to the Concentrator Feed Make-up Tank (CFMT) housed in the VB. The slopes are such that, under a no-pumping condition, the pipes drain away from the VC and back into the waste tanks.

4. VC—The VC is a thick, reinforced concrete structure that is seismically qualified. It is the primary passive confinement system for the VP. The cell has several penetrations and viewing windows. The penetrations are used for inlet piping for the transport of waste slurry and chemical glass formers to the CFMT. They also accommodate the various instrumentation leads and probes and support the remote operations of the cell. The windows are viewing ports, and they are both seismic- and tornado-resistant. The walls of the VC are lined with 304L SS to facilitate decontamination and provide containment. The VC also houses cranes and other operations support equipment.

   Cold Chemical Mix Tank and Shim Mix Tank—These are tanks in the CCB providing nonradioactive material to the CFMT or the Melter Feed Hold Tank (MFHT). (NOTE: These process vessels are not in the VC, but feed into it.)

   CFMT—In this tank, the glass formers and chemicals are mixed with the HLW from Tank 8D-2 and the effluent from the Submerged Bed Scrubber (SBS). The feed mixture in this tank is concentrated and analyzed to ensure the acceptability of the product before it leaves the tank.

   MFHT—This tank holds the feed from the CFMT and provides a constant feed to the Slurry-Fed Ceramic Melter (SFCM). It has the same available volume as the CFMT. Homogeneity of the feed is maintained with the use of a mechanical agitator.

   SFCM—This melter is at the heart of the VP. It is an electrical melter that will dry and then melt the slurry to form glass. The heating elements for the melter consist of three plate electrodes. The electrode assembly is cooled by utility air. Under low flow conditions (i.e., loss of cooling), there is no automatic shutdown of the melter, and operator action is required. The melter is constructed with highly corrosion-resistant refractory liner and shell materials.

5. Solid Waste Stream—Once the molten glass is prepared in the SFCM, the solid component of the waste passes through the following components:

   Turntable—HLW canisters are placed on a turntable located beneath the SFCM. The turntable holds four canisters at any given time. These canisters collect the molten glass and undergo a slow-cooling process. A minimum of 80 percent of the volume of each canister is filled.

   Welding Station—Lids are placed on top of the canister and welded in place at the welding station. The welding station is located close to a cell wall from where the process can be

observed. The welding system is an autogenous pulsed Gas Tungsten Arc Welding (GTAW) system.

Decontamination Station—The capped HLW canister undergoes a decontamination process at this location. The decontamination is performed by a chemical process. A smear test is used to judge acceptability after the decontamination. The liquid HLW from this process is fed back to the SBS and finally to the CFMT.

Canister Transportation Through Tunnel—Loaded HLW canisters are transported from the VC via a tunnel into the interim storage area. The tunnel is the link between the newly constructed cell structure, which is a confinement barrier, and the storage facility.

HLWIS—The HLWIS has metal racks where the canisters can be stacked. This facility is housed in a modified part of an existing structure and is not part of the VC.

6. Gaseous Waste Stream—The gaseous components of the HLW coming into the VC from Tank 8D-2 and those generated by the operation of the VF are controlled by the Vessel Ventilation and Off-Gas systems, which comprise the Process Off-Gas System. The Vessel Ventilation system collects the gases from all the vessels except the SFCM. It joins the Off-Gas system after the SBS and HEME components for further processing. After the in-cell processing, the gases are transmitted to the ex-cell through an isolated duct. The entire gaseous waste stream is confined in tanks and piping until it reaches the stack. The components that are important in the gaseous stream are:

   - Melter off-gas
   - Film cooler (Melter Pressure Control) and brush
   - SBS
   - High efficiency mist eliminator (HEME)
   - Re-heaters, Pre-heaters
   - Pre-filters—High efficiency particulate air filter (HEPA)
   - Vessel vent header and condenser
   - Off-gas trench
   - 01-14 equipment
     - Re-Heater, HEPAs #1 & #2, blowers, pre-heater, oxides of nitrogen (NOX) Treatment (Ammonia & Catalytic Reactor)
   - Stack, monitors and by-pass relief valve

7. HVAC—The purpose of the HVAC system is to maintain an acceptable thermal and air quality environment for operations personnel and to direct air flow to facilitate the minimization of contaminant transport to zones of greater contamination potential within the VF. The HVAC system is zoned using a concept of cascading pressures. At all times there is a negative pressure within the VC as compared to the ex-cell. This enables flow of air into the cell and confines any contamination from propagating to the outside. As designed, any failure of the HVAC system will direct all gaseous flows from the VC through the Secondary Filter Room (SFR) and out to the stack. The components that are important in the HVAC system are:

- Ventilation Zones, Concept of Cascading Pressures, Control In-Cell
- Confinement—Doors and Windows, Infiltration
- Prefilters—Dioctyl Phthalate (DOP) Testing, Seismic Qualification, Screens
- In-Cell Coolers—Shared Cooling Tower Water (CW) with Ex-Cell Coolers
- SFR
- Flexible Connectors
- Secondary HEPA Filters, Redundancy, Plenum Division
- Stack—Monitors, By-pass Relief Valve
- Control Room (CR), Operating Aisle Ventilation

8. Transfer Pits and Trench Ventilation—The transfer pits and trenches have thick concrete structures with drains that facilitate flow back into the waste tanks. The pits have single-wall jumpers to direct flow of the waste. The ventilation system for the pits and trenches is independent of that of the VF. The most important function of the ventilation is during maintenance operations. During the vitrification operations, the pit covers are in place, and a slightly negative pressure ensures backflow into the waste tanks.

1.4 OUTLINE OF SAFETY EVALUATION REPORT PRESENTATION

The presentation format in this report reflects a combination of NRC and DOE practices in preparing SERs. Unlike SERs that have a formal role of accepting or rejecting the assessments in the SARs, this SER is intended to provide guidance to the DOE on radiological issues relating to the VP at WVDP. This approach is consistent with the NRC-DOE MOU.

The major part of the CNWRA review of the WVNS-SAR-003, Revision D, is presented in Section 2 of this report. In Subsection 2.1.1, the potential hazards at the site due to natural and human-caused events and the appropriateness of the choices are discussed. The VF design considerations and how the various components are designed and analyzed are presented in Subsection 2.1.2. This subsection deals with the safe operations aspect of the VF. Evaluations of the designs of particular structures, systems, and components whose functions are important to radiological safety are contained in Subsection 2.1.3. An assessment of the administrative features and their impact on safety is provided in Subsection 2.1.4. Following the design evaluation, the management of waste generated in the vitrification campaign and the potential radiological doses during the plant operations are discussed (Subsections 2.2 and 2.3). Subsection 2.4 discusses the accident analysis presented in the WVNS-SAR-003, Revision D. Here, the capacity of the various passive confinement barriers under conditions beyond design basis accidents (BDBAs) is addressed.

Section 3 discusses other safety considerations that affect design and operations not discussed in Section 2. Also, Section 3 summarizes the special studies and reviews conducted during the NRC review process. Section 4 is a general presentation of interface issues that could arise from different operations or from nonradiological safety questions and that has a bearing on the overall radiological safety at the VF.

Conclusions based on the overall evaluation and a few operational recommendations are presented in Section 5. Results of independent evaluations performed by the NRC team on specific technical topics are incorporated into this document.

Dimensional units used in this SER are based on values taken from WVNS-SAR-003, to facilitate reference to that document. As a result, no attempt was made to convert the units from WVNS-SAR-003 to a consistent set of units for this SER.

References to site-specific operating procedures, QA documents, fire protection manuals, etc. (e.g., WVDP-106, WVNS-110, WV-984, TSD-A.3.6.B, WVNS-DC-046) are given in the appropriate SARs and are not reproduced in this SER.

2 SAFETY ANALYSIS REPORT AND SUPPORTING DOCUMENTATION REVIEW

This section presents the detailed evaluation of the WVNS-SAR-003 and supporting documents conducted by the NRC and its subcontractor, the CNWRA. The various sections provide both the background on the topics and their associated evaluations. Covered in these evaluations are hazard treatment, design and design philosophy, operational aspects, and accident analysis for the vitrification program. The background information provided is brief, and the reader is referred to the WVNS-SAR-003 for additional details.

2.1 ADEQUATE CONTROL OF HAZARDS

The hazards associated with the VF may occur during two major conditions including:

(i) Normal Operations[1]

(ii) Accidents

This discussion of the source of the hazards will follow the general process that the HLW undergoes in the VP. 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 (passive confinement) is the major protective means of confined hazards, while ventilation (active confinement) is used to control doses from airborne materials.

At the beginning of the process (transfer of the waste from the tanks to the VC), the primary confinement is the waste transfer line. The waste transfer line is only used on approximately 7- to 8-day intervals. The line is flushed with water after each transfer to eliminate most contamination, thus significantly reducing the hazards. The concrete trenches containing the waste transfer lines constitute the secondary confinement during this process.

Subsequently, the confined sources of HLW are largely located within the VC. The vessels containing the bulk of activity include the process vessels (CFMT, MFHT, and SFCM), the solid waste stream (turntable and filled HLW canisters), and the gaseous waste stream (SBS, HEMEs, and HEPA filters), which includes entrained particulates. The process vessels provide the primary confinement while the VC provides the secondary confinement of the waste. 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 using the active confinement systems.

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, which are not discussed in this SER. The reader is referred to the WVNS-SAR-003 for details.

[1] Refer to Section C.5.2.2.1.2 in WVNS-SAR-003

2.1.1 Identification of Hazards

Based on the guidelines given in UCRL-15910 (Kennedy et al., 1990), there are four basic steps required in the identification of hazards for the facility. These steps provide a logical basis for the discussion given in the SER. They include:

- The usage categories and performance goals for the VF have been established. The West Valley facility is considered a Moderate Hazard Facility (facilities where confinement of contents is necessary for public or employee protection). The performance goal for the facility is an annual probability of exceedance of 10^{-4} or less, with respect to damage, to the extent that the facility cannot perform its function. Additional information is contained in Section 2.1.2 of this document.

- For each category, the hazard probability was specified, and hazard loads were developed. This step includes the site selection and evaluation process. The major hazards considered in the design of the West Valley facility are the seismic and tornado events. These events, in conjunction with the normal operating loads, provide the design basis for the facility. Details are presented in Section 2.1.2 of this document.

- For each category, design and evaluation procedures to evaluate facility response to hazard loads were utilized. Both basic structural adequacy and component functional adequacy were addressed. The major elements of the facility were designed using either equivalent static or dynamic linear elastic analysis techniques. General information on the design and evaluation procedures are contained in Section 2.1.2 of this document. Details relating to specific systems in the VF are contained in Section 2.1.3 of this document.

- For each category, criteria were applied to assess whether or not computed response was acceptable. The primary concern in this review was radiological release. Therefore, the review process includes both damage estimation and release fraction calculation [LA-10294-MS (Elder et al., 1986)]. Details relating to specific systems in the VF for normal hazards are contained in Section 2.1.3 of this document. Details for accident conditions are contained in Section 2.4 of this document.

The WVNS-SAR-003 was reviewed in relationship to these steps to ensure completeness of the suite of hazards identified.

The complete set of hazards will be based, in part, on the loads used in the design of the VF. They are divided into three basic groups: (i) normal operating load conditions, (ii) severe environmental load conditions, and (iii) extreme environmental load conditions. The normal operating load conditions, those loads that are encountered during normal plant operations and shutdown, are discussed below.

Dead Load (D)—Dead loads include the weight of structures and structural components, equipment, piping, walls, partitions, platforms, conduit, cable trays, and all other static gravity loads. Fluids or solids contained within the equipment or piping are also considered a dead load (Dames & Moore, 1994a).

Live Load (L)—Live loads include floor and roof area loads, crane loads, layout loads due to temporary placement of movable equipment or structures, equipment handling loads, and vibratory and impact loads from equipment and other processing loads (Dames & Moore, 1994a).

Thermal Load (T_0)—The VF structures were designed to withstand the thermal loads due to expansion, contraction, thermal gradients through structural shield walls, slabs, and beams, and thermal expansion/contraction of structural steel framing members (Dames & Moore, 1994a). The outdoor design conditions are 78 °F (Summer) and 22 °F (Winter). Indoor design conditions vary with location and range from 65 to 95 °F. For all thermal analysis, the as-built condition is assumed to be 65 °F (Dames & Moore, 1994a). For the High-Level Radioactive Waste Transfer System (HLWTS) piping, the temperature of the fluid was conservatively taken as 220 °F (Dames & Moore, 1994b).

Internal Pressure (P_0)—All the primary concrete structures in the VF have been designed to resist a negative pressure of 15.6 lb/ft^2 (3 in. of water). This internal pressure loading is the result of the cell ventilation system designed to maintain a pressure drop between the exterior and the interior of the building (Dames & Moore, 1994a). For the HLWTS piping, the internal pressure is taken as 150 psig (Dames & Moore, 1994b).

Soil Pressure Load (H_{static}, $H_{hydrostatic}$, $H_{dynamic}$)—These loads include soil pressures exerted on the structures by the backfill and the surcharge. Both static and dynamic soil load conditions are used (Dames & Moore, 1994a).

Differential Settlement (D)—An allowable differential settlement of 1/4 in. has been specified for design of the facility in the WVNS-SAR-001. Analysis has demonstrated that the differential settlement will be negligible (Dames & Moore, 1994a). For the concrete trenches in the HLWTS, the ultimate differential trench movement was 0.12 in. Since the piping was not installed in the trench for more than 2 yr after the trench was constructed, static differential displacements were not considered part of the analysis of the HLW transfer piping (Dames & Moore, 1994b).

> *Evaluation: The normal operational loads defined for the VF are in conformance with standard engineering practice [American National Standards Institute (ANSI)/American Society of Civil Engineers (ASCE) 7-88 and Uniform Building Code, UBC] as modified for site-specific and operational considerations. The specific influences of soil pressures and differential settlement have been adequately addressed.*

The severe environmental load conditions are those loads that could infrequently be encountered during the plant life and are discussed below.

Snow Load (S)—Buildings and structures are designed for the following snow load conditions: 1,915 Pa (40 lb/ft^2). The resulting loads are relatively small (less than 10 percent of the dead load) compared to other design requirement loads. This load definition is the same as that given in Figure 7 of ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988).

Wind Load (W)—Building structures and equipment on the exterior of the buildings are designed for wind loads with the following parameters.

- 100-year wind of 35.8 m/s (80 mph)

- Peak gusts of 43.4 m/s (97 mph)

- Based on ANSI A58.1 (American National Standards Institute, 1982) Exposure Condition C

The wind loads given are in agreement with the values given in Figure 1 of ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988).

Evaluation: The severe environmental loads defined for the VF are in conformance with standard engineering practice [ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988) and UBC (International Conference of Building Officials, 1988] as modified for site-specific considerations. These loads are appropriately included in the margin of safety calculations.

The extreme environmental load conditions are those loads that are credible but highly improbable and include the following.

Lightning—The VF has lightning protection equipment/devices consistent with the requirements of applicable industrial standards.

Flooding—VF structures are located at elevations at least 14 ft above potential flood levels due to the 100-yr storm and probable maximum precipitation (West Valley Nuclear Services Co., Inc., 1994a).

Seismic Load (E_{DBE})—Earthquakes are one of the extreme environmental conditions that form the critical design basis events and control the safety margins for natural phenomenal hazards. These design basis events meet or exceed DOE Order 6430.1A (U.S. Department of Energy, 1989) and UCRL-15910 (Kennedy et al., 1990) guidance for natural phenomena. Site characteristics and analysis for natural hazard phenomena are contained in sections of the WVNS-SAR-003 and are based on information in WVNS-SAR-001 and the accompanying Technical Support Documents (TSDs).

Tornado Load (W_t)—Tornadoes are one of the extreme environmental conditions that form the critical design basis events and control the safety margins for natural phenomena hazards. These design basis events meet or exceed DOE Order 6430.1A (U.S. Department of Energy, 1989) and UCRL-15910 (Kennedy et al., 1990) guidance for natural phenomena. Site characteristics and analysis for natural hazard phenomena are contained in sections of the WVNS-SAR-003 and are based on information in WVNS-SAR-001 and the accompanying TSDs.

Others—Other site-specific loads are enveloped by the loads above.

Evaluation: The extreme environmental loads defined for the VF are in conformance with standard engineering practice [ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988), UBC (International Conference of Building Officials, 1988), and NFPA (National Fire Protection Association, 1993), ANS-2.8-81 (American Nuclear Society, 1981)] as modified for site-specific considerations. For lightning, no specific review of the facility design was performed (i.e., it is assumed that the statement the design is in accordance with the NFPA requirements is correct). Details of the flooding conditions are contained in TSDs for WVNS-SAR-001 (TSD A.3.4-A, A.3.4-B, A.3.4-C). The seismic and tornado loads are

discussed in detail in subsequent sections. Based on an overview of the design of the facility, the loads used in the design and analysis are complete.

2.1.1.1 Seismic Loads

The primary seismic hazards are ground motion and differential ground motion. The ground motion can cause structural failure of buildings as well as failure of components within the buildings due to either peak overload or dynamic responses. Differential ground motion can often lead to failure in underground piping systems, especially where they enter "rigid" structures, as well as contact between two adjacent structures. Additional hazards due to the seismic event may also include liquefaction, slope instability, and ground settlement.

As background for the discussion on the seismic loads, a historical perspective of the West Valley seismic design/evaluation is given based on presentations made by Dames & Moore at the review meeting held in February 1995 (Rowland, 1995). The nuclear fuel reprocessing plant was initially designed in accordance with the 1961 UBC Seismic Zone III requirements (International Conference of Building Officials, 1961). Construction of the facility was accomplished between 1963 and 1966. In 1976, a plan was presented for relicensing of the fuel reprocessing facility. At this time, requirements for a safe shutdown earthquake (SSE) with a 0.2 peak ground acceleration (PGA), based on 10 CFR Part 100, Appendix A, were established by the NRC. This plan was eventually withdrawn.

Beginning in 1982 and continuing through 1995, several reassessments of the seismic design/evaluation criteria were made for the WVNS by Dames & Moore. In 1983, Dames & Moore completed a site-specific, probabilistic study that recommended a 0.07 PGA based on the 85 percent hazard curve (Dames & Moore, 1983). In 1987, the NRC accepted a 0.1 PGA for the Design Basis Earthquake (DBE) (comparable to the SSE) and suggested that margins should satisfy a 0.2 PGA event without failure of confinement. The VF and supporting equipment were designed in accordance with 0.1 PGA for horizontal motion and 0.067 PGA for vertical motion. A second probabilistic seismic hazard analysis, based on Electric Power Research Institute (EPRI) procedures, was completed by Dames & Moore in 1992 (Dames & Moore, 1992). These two reviews provided the basis for the information presented in the TSDs for WVNS-SAR-001 (TSD A.3.6-A to A.3.6-I). A final study (Dames & Moore, 1995) was completed in 1995. The 1995 analysis incorporated both EPRI (Electric Power Research Institute, 1986; 1989) and Lawrence Livermore National Laboratories (LLNL) (Bernreuter et al., 1989; Sobel, 1993) probabilistic risk analysis for the eastern U.S. using procedures developed in DOE-STD-1024-92 (U.S. Department of Energy, 1992).

The seismic hazards at the WVDP site were also compared to those at the Ginna Nuclear Power Plant (NPP), the closest NPP to the West Valley site. Based on information provided in the review meeting (Rowland, 1995), Ginna was designed based on the following parameters. The facility was licensed in 1968 based on a DBE with a 0.12 PGA using a deterministic analysis. In 1973, the siting requirements were set as: an SSE with a 0.20 PGA (6×10^{-5} annual probability) and an Operations Based Earthquake (OBE) with a 0.08 PGA. The hazard risk analysis for this NPP was deterministic based on the maximum credible event (Rowland, 1995).

From this historical background, it can be seen that the basis for definition of the seismic environment for the West Valley site has evolved over time. The original design was a deterministic assessment of the seismic event based on UBC requirements. The more recent assessment has been based on a process hazard analysis (PHA) using the procedures established by EPRI and LLNL. These

probabilistic procedures form the bases for proposed changes to 10 CFR Part 100 and 10 CFR Part 50 to allow for their use in the assessment of NPPs (Nuclear Regulatory Commission, 1994).

The basic requirements for seismic design for the VF comes from DOE Order 6430.1 (U.S. Department of Energy, 1983) which specifies that seismic resistance must be provided in critical facilities to withstand a DBE [LA-10294-MS (Elder et al., 1986) and references to DOE Order 6430.1 (U.S. Department of Energy, 1983)]. The DBE is also defined as an SSE. Because the DBE must be assumed to occur at any time, certain loads, such as common wind, snow, or intermittent maximum loading, should be added to earthquake loading.

The DBE has the following characteristics as defined in the WVNS-SAR-003:

- Annual probability of exceedance of 5.0×10^{-4} based on a median hazard curve from a site-specific probabilistic analysis (Dames & Moore, 1983) (Figure 2-1)
- Horizontal—0.1 PGA
- Vertical—0.067 PGA (defined as 2/3 of the vertical component)
- Design spectra in accordance with NRC Regulatory Guide (RG) 1.60 (Nuclear Regulatory Commission, 1977a)
- Design structural damping in accordance with NRC RG 1.61 (Nuclear Regulatory Commission, 1973)

It should be noted that the definition of the DBE was used as a basis for the design of the VF during the 1982 to 1995 time frame (i.e., all new construction). Based on the 1987 suggestions by the NRC, for a margin of safety of greater than 2.0×DBE (0.1 PGA), a re-evaluation of the seismic hazard was done. The bases for the re-evaluation were updated information on the site characteristics and reduction of the conservatism in the analysis parameters. The methods used and the results of this re-evaluation follow.

The WVDP is located in a region of New York state characterized by relatively sparse seismic activity. No historical earthquake of magnitude 6 or greater has occurred within about 200 miles (320 km) of the WVDP site (Dames & Moore, 1995). Details of the site characteristics are given in TSD A.3.6-A (Regional and Site Geology), TSD A.3.6-B (Borehole Logs), and TSD A.3.6-C [Tectonic Provinces of the Site Region (Revision A)] from WVNS-SAR-001.

Evaluation: No independent review of the local geologic and tectonic provinces was performed. Checks were made relating the resulting PGA levels to those of the Ginna NPP established by EPRI and LLNL. Based on a review of the TSDs and the comparison of PGAs, it is concluded that this information is correct.

The historical background has indicated that a number of approaches have been utilized to define the seismic event. These approaches were based on the state-of-the-art procedures available at the time. The following discussion concentrates on the PHA since these levels were used in the evaluation of the safety margins. Two separate approaches (LLNL and EPRI) are discussed, in addition to DOE procedures to incorporate both into a common analysis. Each of these has established procedures for accomplishing

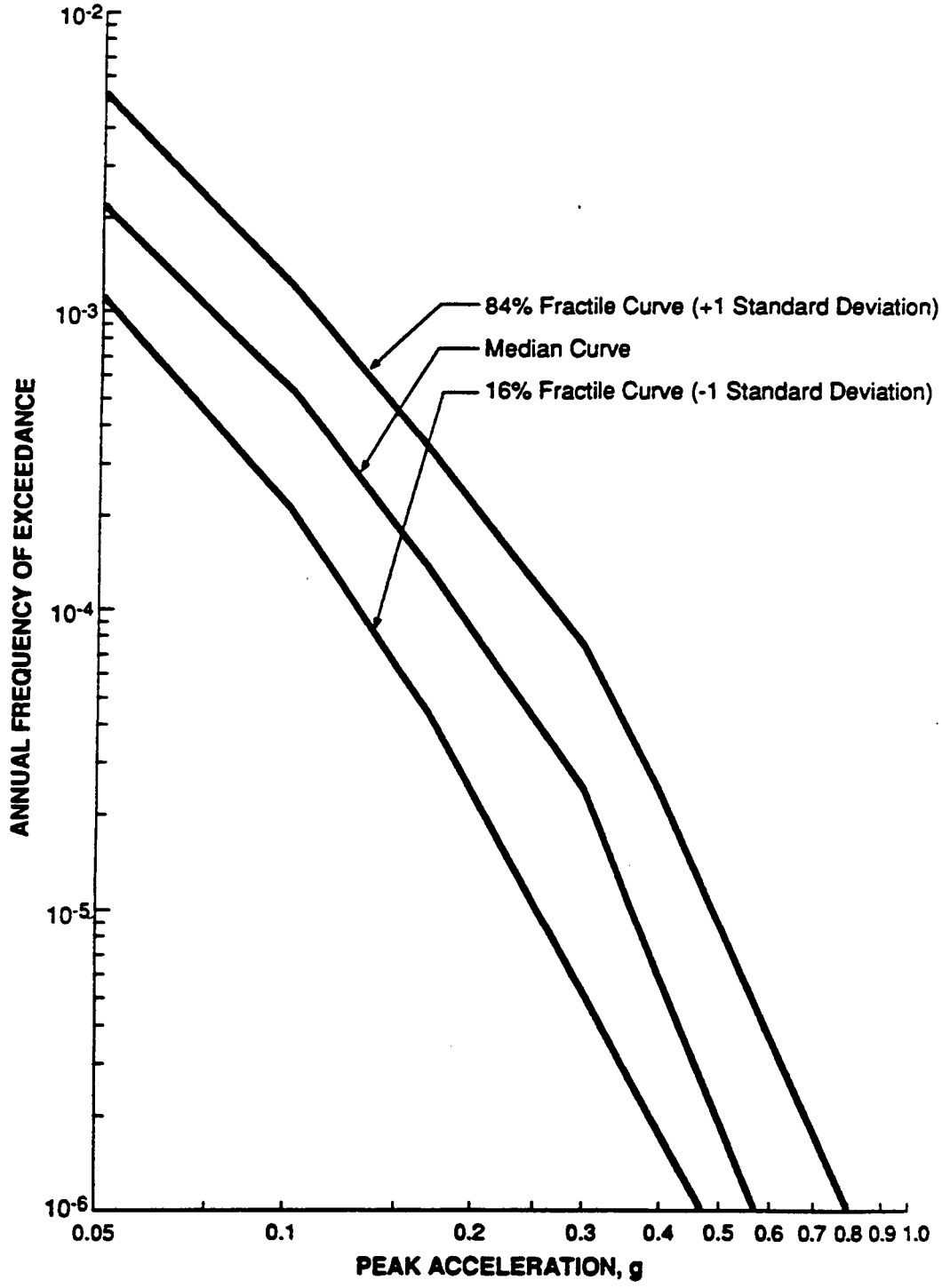


Figure 2-1. Fractile seismic hazard curves (Dames & Moore, 1983)

the definition of the peak amplitude for the seismic level as given in ASCE 58-80 (American Society of Civil Engineers, 1980).

The LLNL procedures for PHA are based on developments by two groups of experts covering the seismic-source and the ground-motion models. The S-expert panel consisted of 11 experts, each of whom developed a source model consisting of the location and earthquake recurrence rates for each seismic source delineated. The information is related to the site geological and tectonic information given in WVNS-SAR-001. The G-expert panel consisted of five experts, each of whom selected a set of attenuation equations for use in the SHA. Combining the results of these two expert panels results in a series of probability curves giving the PGA as a function of the annual probability of exceedance. The original LLNL results (Bernreuter et al., 1989) were later revised based on new recurrence rates and ground-motion attenuation models and is presented in NUREG-1488 (Sobel, 1993). These studies represent the entire eastern and central U.S., including NPPs near the WVDP site.

The EPRI procedures for PHA begin with development of seismic source models by the six EPRI consultant teams. Again, these are related to the site geological and tectonic information given in WVNS-SAR-001. Three attenuation equations were used in the original EPRI SHA calculation for the eastern United States sites. These results were later updated with new attenuation curves. Combining the results of the seismic source teams with the attenuation equations provides a probabilistic estimate of the seismic loads at a given site (Electric Power Research Institute, 1986; Electric Power Research Institute, 1989).

New Eastern United States attenuation equations have been developed that should be considered as replacements to some earlier equations. Furthermore, Dames & Moore (Dames & Moore, 1995) state that it is acknowledged that the Nuttli attenuation equations (Bernreuter et al., 1989) are too conservative and should be discarded from both the EPRI and LLNL methodologies. A similar comment applies to the Triifunac/Gupta-Nuttli equations used in the original LLNL methodology (Bernreuter et al., 1985). "The use of an appropriate set of attenuation equations in the EPRI and LLNL methodologies would probably not appreciably affect the PGA or short-period PSV estimates for WVDP, but their use would probably result in lower response spectral values at periods around 1 second" (Dames & Moore, 1995).

The following discussion relates the application by Dames & Moore of these two procedures to the West Valley site. It is taken directly from the executive summary of Dames & Moore (1995).

> "The ground-motion hazard at the WVDP site was evaluated based on information in publications by the EPRI and LLNL that pertain to seismic hazard analyses of NPP sites in the central and eastern United States. In particular, the data in these publications relevant to the seismic hazard at the Ginna NPP site were reviewed. The Ginna site is approximately 145 km NE of the WVDP and is the closest NPP to WVDP. Based on a review of the location of the seismic sources affecting the ground-motion hazard at the Ginna site, it was concluded that the bedrock ground-motion hazards at the Ginna and WVDP sites were similar. This conclusion was supported by comparing the results of seismic hazard analyses at WVDP, conducted by Dames & Moore (1992) using the EPRI hazard analysis methodology, with the EPRI results published for Ginna. The EPRI and LLNL results for Ginna were then combined following DOE Standard DOE-STD-1024-92. The resulting PGAs and 5% damped pseudovelocity (PSV) response spectra were modified to account for the ground-motion amplification due to the local geology at the WVDP vitrification plant site.

The values of PGA at the 1×10^{-3} and 5×10^{-4} annual probabilities were 0.053 g and 0.078 g, respectively. These values and the corresponding response spectra are below the WVDP DBE represented by the NRC 1.60 (Nuclear Regulatory Commission, 1977a) design spectra normalized to a PGA of 0.10 g. Based on this result, a re-evaluation of the DBE for WVDP is not considered necessary (Dames & Moore, 1995)."

Table 2-1 was developed by Dames & Moore to compare the results of the probabilistic SHA for the West Valley site based on the EPRI procedures with the independent results for the Ginna NPP. The table gives the bedrock PGA levels for one probability level, 5×10^{-4}, corresponding to the specified level for the DBE given in WVNS-SAR-003. This is the level recommended in DOE-STD-1020 for Performance Category 3 (U.S.DOE, 1994). The results for both locations are similar. The mean probability curves for both sites are given in Figure 2-2.

Table 2-1. Comparison of bedrock peak ground acceleration at a probability of 5×10^{-4}/yr (from Dames & Moore, 1995)

Level	EPRI WVDP	EPRI Ginna	LLNL Ginna
Median	0.055 g	0.045 g	0.035 g
Mean	0.075 g	0.053 g	0.073 g

Once the PGA level has been established, it is necessary to develop the damped response spectrum representative of the site. DOE-STD-1024-92 (U.S. Department of Energy, 1992) recommends an approach to compute the 5 percent damped response spectrum associated with the target probability level from the EPRI and LLNL SHA results. The approach is to first compute the geometric average of the median PGA values for the EPRI and LLNL studies for the target probability. These PGA values are then multiplied by a factor to convert to a mean value. This mean PGA value is the anchor acceleration for a median spectral shape defined in NUREG/CR-0098 (Newmark and Hall, 1978) or a site-specific median spectral shape derived from deterministic methods (Dames & Moore, 1995). Table 2-2 compares the EPRI and LLNL procedures for the Ginna NPP.

Table 2-2. Ginna Rock Site Median pseudovelocity at 5×10^{-4}/yr probability (from Dames & Moore, 1995)

Frequency Hz	EPRI	LLNL
1.0	0.88 cm/s	1.59 cm/s
2.5	1.26 cm/s	1.81 cm/s
5.0	1.28 cm/s	1.47 cm/s
10.0	1.00 cm/s	1.03 cm/s
25.0	0.47 cm/s	0.35 cm/s
∞	0.045 g	0.035 g

It was then necessary to adjust the bedrock values to account for the soil characteristics of the site. The WVDP site is known to consist of shallow stiff soil over bedrock, and the potential amplification of ground motion due to these soils exists (Dames & Moore, 1995). To account for the soil characteristics, the shallow soil factors from Toro and McGuire (1987), which increase with increasing period, were applied to the uniform probability ground motion values (Dames & Moore, 1995). The

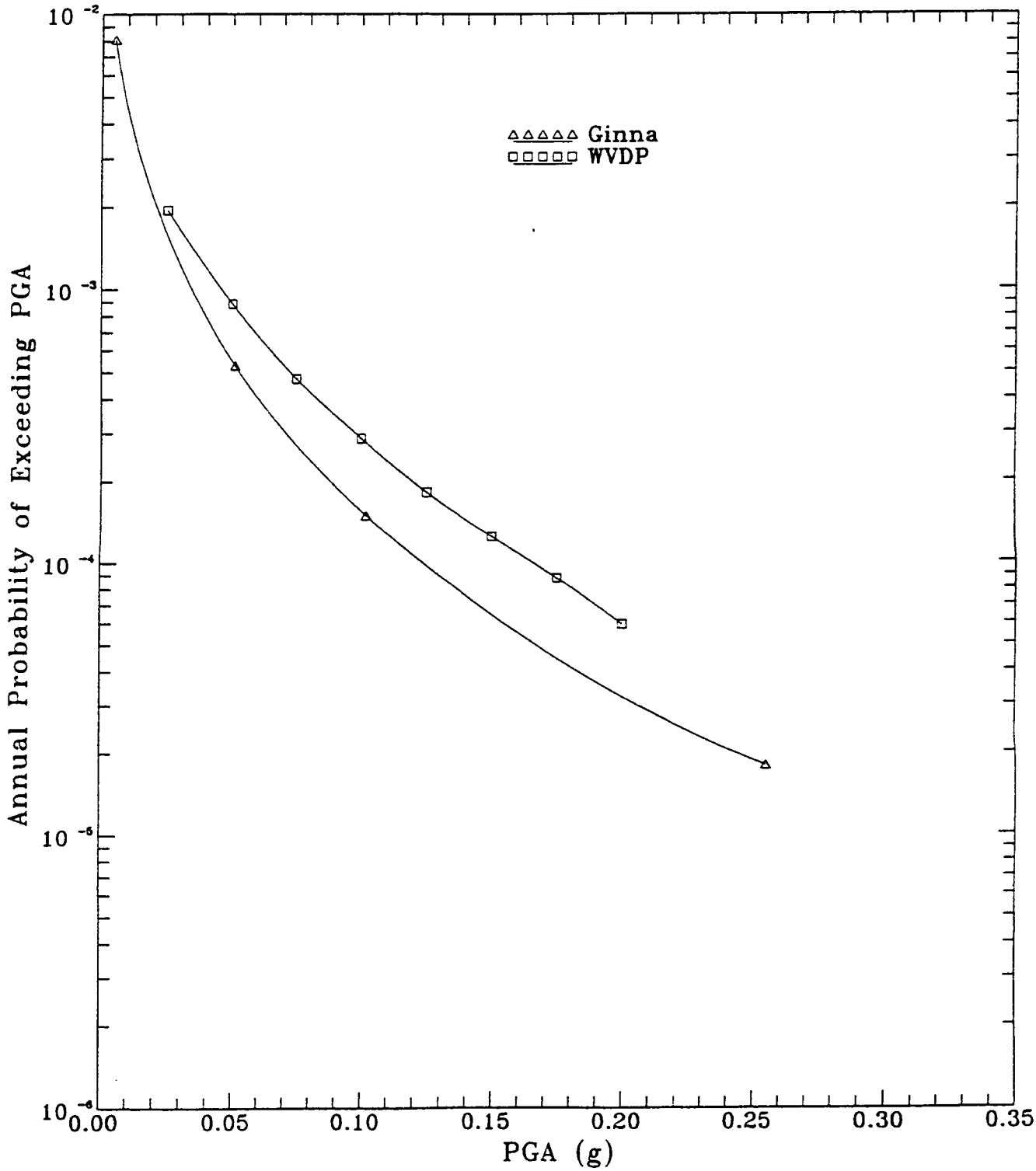


Figure 2-2. Electric Power Research Institute Methodology—West Valley Demonstration Project versus Ginna mean probability curves (rock site) (Dames & Moore, 1995)

resulting spectra values are given in Table 2-3 and are shown in Figure 2-3. The important point to note is that the design spectra for the DBE, RG 1.60 (NRC, 1977a), is significantly higher than the other values, DOE-STD-1024 (U.S.DOE, 1992) and uniform probability, throughout the majority of the frequency range. This high design spectra for the DBE may result in a conservative estimate of the true margins of safety.

Table 2-3. West Valley Demonstration Project soil site ground motion spectra (from Dames & Moore, 1995)

Frequency	Uniform Probability, 5×10^{-4}/yr	DOE STD 1024	WVDP DBE
1.0	4.29 cm/s	15.7 cm/s	23.0 cm/s
2.5	4.48 cm/s	10.3 cm/s	19.5 cm/s
5.0	2.94 cm/s	5.16 cm/s	8.85 cm/s
10.0	1.67 cm/s	2.29 cm/s	3.77 cm/s
25.0	0.80 cm/s	0.56 cm/s	0.77 cm/s
∞	0.078 g	0.078 g	0.10 g

Therefore, the PGA and the response spectra for the horizontal components of the seismic event have been established. Based on early information (American Society of Civil Engineers, 1980), indications were that the use of a vertical spectra equal to 2/3 of the horizontal spectra may not be appropriate for eastern United States earthquakes. More recent information (Electric Power Research Institute, 1993; Atkinson, 1993; Boore and Atkinson, 1992; Gupta and McLaughlin, 1987; McGuire, 1986) presented by Dames & Moore at the February 1995 meeting (Rowland, 1995) indicates that for a location distant from the source, typical of the West Valley site, the 2/3 value is appropriate.

Evaluation: The PGA level at the site is acceptable based, in part, on the conclusions drawn from the comment resolution meeting held at West Valley on February 14–17, 1995, among the DOE and their contractors and NRC and CNWRA (Rowland, 1995). Comment resolution related to the seismic analyses for the WVDP is based on clarification of a number of issues including a definition of the design basis seismic event.

The annual probability of exceedance for DBEs as defined in WVNS-SAR-003 is based on DOE-STD-1020 (U.S. Department of Energy, 1994), with an earthquake annual probability of 5×10^{-4}. The DBEs, in general, conform to the definition of OBEs for nuclear reactor designs. The Beyond Design Basis Earthquakes (BDBEs) are consistent with the definition of an SSE for reactor designs and have an annual probability in the range of 1×10^{-6}.

Following the comments by both the NRC and DOE-EH-11 on the earlier versions of the seismic analyses, WVNS conducted extensive studies to evaluate regional seismicity. They provided information at Ginna and the WVDP site based on two

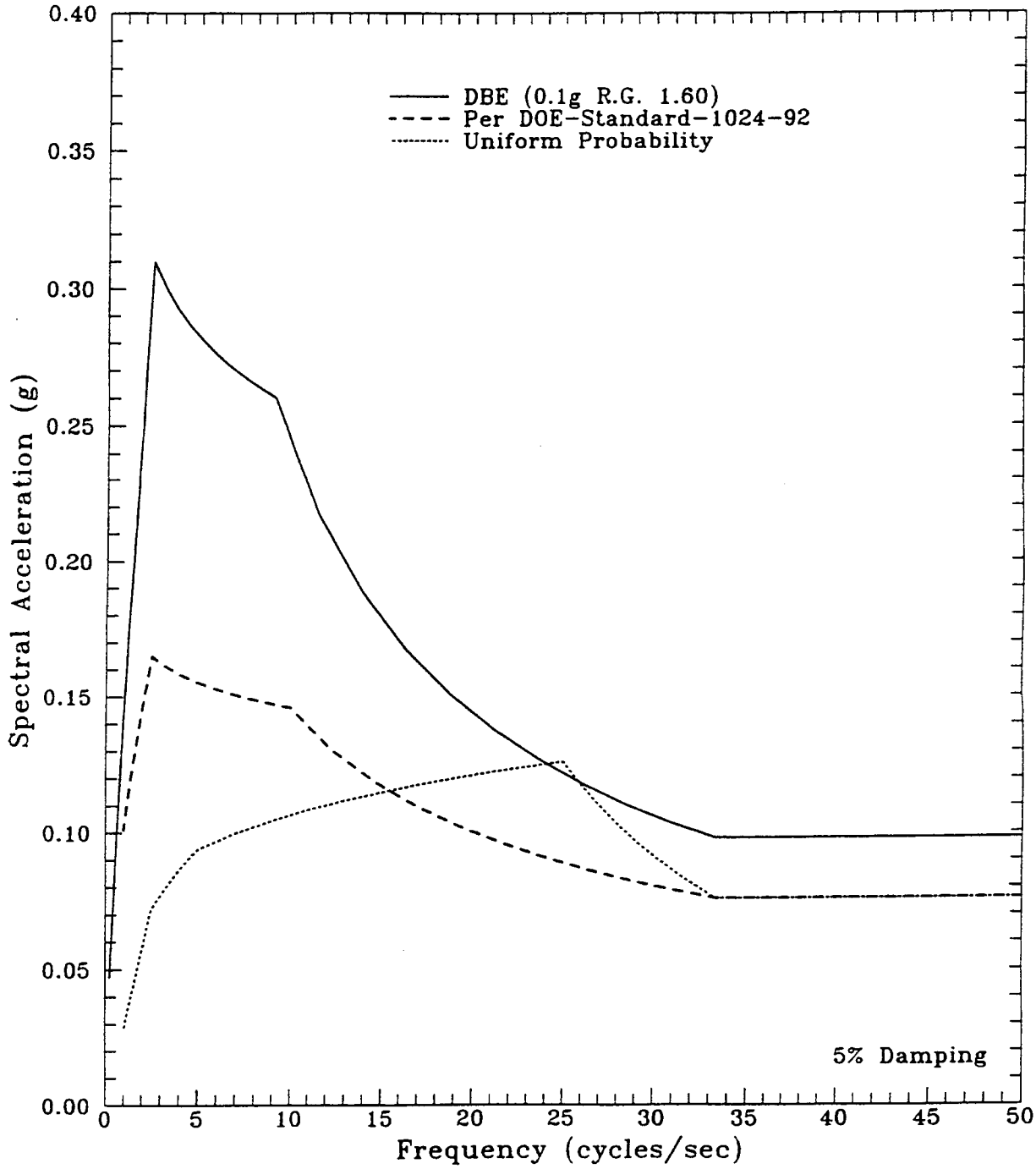


Figure 2-3. Comparison of response spectra (Dames & Moore, 1995)

detailed studies by EPRI and LLNL. It was concluded that the earthquake hazard at West Valley is similar to Ginna (Bedrock). Using this revised evaluation and current guidance in DOE Standards 1020 (U.S. Department of Energy, 1994) and 1024 (U.S. Department of Energy, 1992), the evaluation basis earthquake is 0.078 PGA, which is less than that used in the design of the facility (0.1 PGA). The values used in the design were determined to be conservative with respect to the probabilistic risk assessment.

WVNS computed the mean PGA from analyses based on the median PGAs obtained from the EPRI and LLNL studies. WVDP site mean ground motion at 5×10^{-4}/yr was obtained using DOE-STD-1024 (U.S. Department of Energy, 1992). Initial calculation of the margin of safety was based on the probability of exceedance curves developed by Dames & Moore in 1983. If this margin of safety is less than 2.0×DBE, updated curves were used and other conservative analysis procedures were taken into account.

Information provided by WVNS in TR-102293 (Electric Power Research Institute, 1993) and published papers (Electric Power Research Institute, 1993; Atkinson, 1993; Boore and Atkinson, 1992; Gupta and McLaughlin, 1987; McGuire, 1986) indicate that, unless directly on or adjacent to earthquake-generating faults, vertical components of acceleration of two-thirds that of the horizontal acceleration are appropriate for eastern U.S. sites.

The required response spectrum for the seismic event used in the design is based on that given in RG 1.60 (Nuclear Regulatory Commission, 1977a). Detailed analysis of the site-specific spectra indicates that the shape of the spectrum is conservative.

2.1.1.2 Tornado Loads and Tornado Missiles

The approach for determining wind pressures on buildings and other structures is considered to be independent of the type of windstorm. For winds, the design must incorporate the effects of pressure, total forces, atmospheric pressure change, and missiles.

The VC confinement structures are designed to withstand the forces of a Design Basis Tornado (DBT) having an annual return frequency of 1×10^{-6}. Although the basic cell structures and ventilation system would continue to function, as required during and after occurrence of the DBT, the tornado could, in theory, generate a missile capable of penetrating the shield windows that extend through the cell wall, thus jeopardizing the confinement integrity. Assuming that only 10 percent of the missiles would reach the cell confinement wall with full force, the area of glass with respect to the total wall area, and the orientation of the missile, the frequency of a missile striking the window with sufficient force to cause penetration is 5×10^{-10}/yr.

Based on the information provided in the WVNS-SAR-003 (detailed analyses of tornado occurrences in western New York State), the DBT characteristics are given below.

- Maximum wind speed — 71.5 m/s (160 mph)
- Rotation speed — 49.2 m/s (110 mph)
- Translation speed — 22.35 m/s (50 mph)

- Radius of maximum rotational wind — 45.7 m (150 ft)
- Peak pressure differential — 2.4 kPa (0.35 psi)
- Rate of pressure drop — 1.0 kPa/s (0.15 psi/s)
- Annual probability of exceedance — 1.0×10^{-6}

The associated parameters for tornado-generated missiles include:

- Wooden plank — 139 lb at 85 mph
- Steel pipe — 76 lb at 50 mph
- Annual probability of exceedance — 1.0×10^{-6}

Evaluation: The parameters associated with the DBT and tornado-generated missiles are in conformance with standard engineering practice (McDonald, 1983; American Nuclear Society, 1983; Nuclear Regulatory Commission, 1974; 1977b) as modified for site-specific conditions.

2.1.2 Design Features

Radiation protective features basic to the design of the VF are dedicated to maintaining radiation doses to members of the general public and the work force as-low-as-is-reasonably-achievable (ALARA). Effective control of radiation doses 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. Their physical design features, together with strict adherence to operational requirements presented in WVDP-0101, provide effective radiation control.

There are two types of provisions to confine radioactive materials during normal and accident conditions.

(i) Passive confinement barriers, including walls, hatches, roofs, doors, and shielded viewing windows. The primary passive confinement structures are the reinforced concrete vault structures that enclose the VC, Crane Maintenance Room (CMR), and Transfer Tunnel. These structures are designed to maintain their confinement during all credible environmental load conditions. These barriers will be discussed in detail in Sections 2.1.2.4 and 2.1.3.

(ii) Active confinement systems or components, including the blowers associated with maintaining a negative pressure (relative to atmospheric pressures) in the VC. These systems will be discussed in detail in Sections 2.1.2.5 and 2.1.3.

Evaluation: The passive/active confinement concept used in the design of the VF is in conformance with standard engineering practice. It conforms to the nuclear design standards contained in 10 CFR Part 50, Appendix A, Criteria 2 and 16.

The basic loads used in the design of the VF were introduced in Section 2.1.1. During the design process it is necessary to combine these individual loads to account for concurrent application of multiple types of load conditions. Three groups of load combinations were used in the design of the VF.

(i) Normal operating load conditions (dead, live, thermal, internal pressure, and soil pressure)

(ii) Severe environmental load conditions (wind and snow) with normal operating load conditions

(iii) Extreme environmental load conditions (tornado and earthquake) with normal operating load conditions

Depending on the type of structure, the factors applied to each load in the load combination process were in accordance with established engineering standards. The three basic type of structures and associated load combinations included:

(i) Load combinations for concrete structures were established in accordance with American Concrete Institute (ACI) 318 (American Concrete Institute, 1992) and ACI 349 (American Concrete Institute, 1990)

(ii) Load combinations for steel construction established in accordance with the American Institute of Steel Construction (AISC) Steel Manuals (American Institute of Steel Construction, 1989; 1991; 1992a)

(iii) Load combinations for piping established in accordance with American Society of Mechanical Engineers (ASME)/ANSI B31.3 (American Society of Mechanical Engineers/American National Standards Institute, 1987)

Refer to the WVNS-SAR-003 for specific values for each of these combinations. The "allowables" for each of the materials under the various loading conditions are also addressed and are in conformance with standard engineering practice.

Evaluation: The load combination procedures used in the design of the VF are in conformance with standard engineering practice [ACI 318 (American Concrete Institute, 1992); ACI 349 (American Concrete Institute, 1990); AISC 5327-84 (American Institute of Steel Construction, 1984); AISC M016-89 (American Institute of Steel Construction, 1989); AISC M015-91 (American Institute of Steel Construction, 1991); AISC M017-92 (American Institute of Steel Construction, 1992a); AISC S341-92 (American Institute of Steel Construction, 1992b); ASME/ANSI B31.3 (American Society of Mechanical Engineers/American National Standards Institute, 1987); and ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988)].

The VF includes basic structural systems, equipment, and components. Each of these has different design features. There are three categories of basic structures.

(i) Confinement barriers required to remain functional under site-specific design basis events. The new engineered confinement barrier structures relied on during accident scenarios, including natural phenomena induced accident scenarios, are as follows:

(1) VC
(2) CMR
(3) Transfer tunnel
(4) SFR
(5) HVAC CR
(6) Diesel generator room (DGR)

For (1) to (6), the following are examined independently where applicable:

Roof
Walls
Cell doors
Cell shield windows
Cell hatches
Cell pipe penetration seals

(7) HLWTS

(ii) Modified existing structures not required to remain functional under site-specific design basis events. The facilities are primarily associated with the storage of the HLW in the solid state. In this state, the potential for release is greatly reduced and, therefore, the design requirements are not as stringent. The modified existing structures include:

(1) EDR
(2) Chemical process cell (CPC), which is now referred to as the HLWIS
(3) CPC CMR
(4) 01-14 Building, with the exception noted in (iii)

(iii) New structures not required to remain functional under site-specific design basis events. These are new structures that are not in the category of confinement barriers. In most cases, these structures are designed in accordance with UBC requirements. The new general construction includes:

(1) Sheet metal building surrounding the VC
(2) CCB
(3) Diesel fuel oil storage tank building
(4) The off-gas pipe trench and new portions of 01-14 Building
(5) Load-in/out area

Because of the multiple types of structures and the wide time frame under which they were designed and constructed, it is not possible to establish one design standard for all facilities. The reader is referred to the WVNS-SAR-003 for specific information on the applicable standards for each system.

In addition, there are equipment, vessels, and components that have the potential of becoming seismic hazards to the confinement barriers because of their shape, size, and/or mass. Identification of the equipment and components is contained in C.5.2.6 of the WVNS-SAR-003. These are the major vessels, equipment, and components within the VC that are designed to maintain structural integrity during potential seismic events in order not to be challenges to the confinement barrier or threats to adjacent components if they were not capable of surviving the seismic events. The design parameters are contained in C.5.3 and C.5.4 of the WVNS-SAR-003.

Evaluation: The structures and equipment, vessels, and components of the VF have been properly identified. The appropriate design requirements have been identified and are in conformance with standard engineering practice (see Tables C.5.2.2.1.2-1, C.5.2.2.1.2-2, C.5.2.2.1.2-3, and C.5.2.2.1.2-4 in WVNS-SAR-003).

2.1.2.1 Design Philosophy

The WVDP design philosophy for control of radiation hazards can be generally characterized as follows: (i) provide passive confinement of radiological releases under all conditions, including Beyond Design Basis Events, which are also referred to in WVNS-SAR-003 as accident conditions; and (ii) provide for survivability of important structures, systems, and components under all design basis event conditions (although functionality is not required under DBE or DBT conditions).

For normal operations, certain active confinement systems (e.g., off-gas processing system, HVAC, etc.) are required to function to maintain cumulative operating releases and doses below pertinent limits. For all cases, multiple barriers are provided for confinement of sources of exposure to radioactivity. Standby power systems are available in case of loss of local electrical power.

WVDP has established Evaluation Guidelines (EGs) that define allowable radiation dose levels for both on-site and off-site cases. The dose levels also correlate with three ranges of event probabilities. The EGs are discussed in Section 2.4. In general, as the probability of the event becomes less, the corresponding allowable radiation dose (which could result from the event) becomes greater.

The design of the facility is such that several redundant confinement barriers are used including:

(i) Storage canisters and processing containers, including piping, tanks, melter, etc., used in passive confinement.

(ii) The building shell and auxiliary items such as the SS liner used in passive confinement. This includes the use of sufficiently air-tight physical boundaries to keep contamination as close to the source as practical.

(iii) Ventilation system filtering and negative pressurization used in active confinement. The objective is to maintain pressure differentials between each confinement zone so that air flow travels from zones of lesser contamination potential to zones of greater contamination potential.

An early WVDP design activity involved classification of structures, systems, and components into safety class and quality levels. The *WVDP Quality List "Q-List,"* WVDP-204, is the "primary source for establishing, identifying, revising, and maintaining an up-to-date listing of safety classes and quality levels" of facilities and systems under the QA Program.

From WVDP-204: Safety class and quality level classifications are based on design criteria documents, including WVNS-DC-022, *Design Criteria, Vitrification of High-Level Waste*. In WVNS-DC-022, the three primary design principles for confinement are (i) use sufficiently air-tight boundaries to keep contamination as close to the source as practical, (ii) use multiple barriers for confinement, and (iii) maintain pressure differentials between confinement zones to promote air flow from zones of lesser contamination potential toward zones of higher contamination potential. Other important

design criteria have been established for the WVDP for various structures and systems (WVNS-DC-046, *Design Criteria, Sludge Mobilization Waste Removal System*; WVNS-DC-048, *Design Criteria, High-Level Waste Interim Storage System*; and WVNS-DC-066, *Design Criteria, Vitrification Load-In Facility*).

A "graded approach" was used to assign quality levels based on increasing levels of quality control as the severity of potential consequences of hazards to safety, health, and environmental impact increased. This system recognizes a gradation in importance of structures, systems, and components to safety. The graded approach is used to demonstrate the meaningful selection of barriers to support the defense-in-depth concept for various parts of the VF. However, there are no prescribed minimum number of barriers that are needed under the graded approach. The WVNS-SAR-003 treats the ALARA issues separately from the graded approach. Many of the ALARA issues are approached from the overall site operations perspective and a design with a minimum dose opportunity for the operating or site personnel. The following is a summary of WVDP implementation of the graded approach in their assignment of hazard classification, safety classification, and quality levels per procedures and criteria given in WVDP-204.

It should be noted that hazards other than radiological hazards were taken into account at WVDP for safety class and quality level determination, but only radiological hazards classification is of concern for this SER review.

During conceptual design, minimum safety and quality levels were assigned for each structure, system, and major component by a group WVDP chose for their pertinent expertise. Also, redundancy, backup capability, testing, higher quality levels, and greater specification requirements were established to provide "defense-in-depth" for systems identified by the group as critical. Safety classification was designated as Class A, B, C, or N. Generally, Safety Class A structures, systems, and components are designed using codes and standards applied at NPP and other nuclear facilities with a potential for very large releases of radioactive material. Safety Class B invokes codes and standards used in nuclear facilities with a potential for moderate releases of radioactivity. Pertinent codes and standards for Safety Class C are similar but less restrictive than for Safety Class B. Safety Class N codes and standards are commercial and manufacturers' standards. Thus, progressively more stringent codes and standards are applied for design, fabrication, installation, tests, and quality requirements to assure corresponding higher reliability. Criteria for safety classification are based on radiological off-site and on-site doses [(effective dose equivalent {EDE})] anticipated to result from potential failure, and they are given in Table 2 of WVDP-204. Tabulated EDEs corresponding to safety classifications correlate to EDEs from the two figures presented in Section 2.4 of this SER. If an item is required to limit radiation dose or other hazards, the consequence of its failure is calculated by bounding analyses, allowance for uncertainties, and conservative assumptions. The highest safety class for any structure, system, or component at WVDP is Class B. Potential releases are limited by the batch process, which limits the maximum available working volume of HLW (that within VC process tanks) which is exposed to an energy source (melter) for dispersion. The HLW at the WVDP is stored in the liquid and sludge inventories in the Tank Farm. Once it is converted to molten glass, the HLW is in a more stable form and not as readily available for dispersion. The solidified and containerized glass is even more stable and is relatively immobile with respect to release during storage.

The quality level specifies the level of review, application, and control of applicable criteria commensurate with the safety classification and the necessary level of reliability for operations. The QA Program, whose implementation is identified by the quality level, is based on ASME-NQA-1 (American Society of Mechanical Engineers, 1989). Quality level classification is based on the safety class, but also

includes service considerations such as operational impacts and cost (e.g., maintenance and replacement schedules and costs). Quality levels are also designated by A, B, C, and N. As a minimum, the quality level must equal the safety class for any given structure, system, or component. The quality level, however, may be assigned a greater level than the corresponding safety class if justified by operational impacts and cost.

Table 2-4, which is taken from Table 3 of WVDP-204 (WVNS, 1994d), succinctly summarizes safety classes, quality levels, and corresponding codes and standards for structures, systems, and components for WVDP. Attachment D to WVDP-204, "Q-List," identifies safety class and quality level for a detailed list of structures, systems, and components of the VF System. The table also identifies various industry standards [e.g., ACI 318 (American Concrete Institute, 1992); AISC M016-89 (American Institute of Steel Construction, 1989); etc.] which were chosen to apply to different components and structures for each safety class and quality level.

Mechanisms by which safety class and quality level are established for a particular item or component of one of the systems in Table 2-4 are given in QM-2, *Quality Assurance Program*, and QM-3, *Design Control*.

The primary factor determining classification of structures, systems, and components is whether or not they provide confinement. Confinement structures must withstand the effects of natural hazards and confine the radioactive material to acceptable levels. Nonconfinement structures need not remain functional under the effects of natural hazards, but they should survive design basis events without collapse and they must remain functional under less severe environmental loading.

For the systems within the scope of WVNS-SAR-003, earthquakes and tornadoes are the extreme environmental conditions that form the two critical design basis events and control the safety margins for natural phenomenal hazards. Section 2.1.1 contains a discussion of these hazards. For important structures, systems, and components, margins of safety have been computed to indicate the factor which can be applied to the DBE or DBT loads before ultimate failure of the component will occur. The definition provided for margin of safety in the WVNS-SAR-003, Draft D, was not completely accurate in that it defined the margin as "the factor by which loads produced by the DBE or DBT can be increased before ultimate failure of the component will occur." The definition for margin of safety would be more correctly stated as "the factor by which loads produced by the DBE or DBT can be <u>multiplied</u> before ultimate failure of the component will occur." Correction of the definition was recognized, however, in the Review Comment Record (Mazzetti, 1994) response to comment 5-036, and it is expected that the definition will be corrected in future WVNS-SAR-003 drafts. Stresses due to loads (dead load, live load, etc.) other than those due to design basis events were accounted for in the calculation of margin of safety, as shown in the example below for seismic loads.

$$M = [U - (D + P_o + T_o)] / E_{DBE}$$

where
- M = safety margin
- U = ultimate capacity
- D = dead load
- P_o = pressure load
- T_o = thermal load
- E_{DBE} = seismic load

Table 2-4. Safety classes, Q-levels, and codes and standards (from West Valley Nuclear Services Co., Inc., 1994d, Table 2.3 of WVDP-204)

Safety Class	Quality Level	Structures	Control and Electrical Systems	Facility Components				
				Vessels/ Vents	Pumps	Valves	Piping	Heat Exchangers
A	A	ACI 349; ASME Sec. III Division 1 Subsection NF	IEEE Class 1E	ASME Sec. III Division 1	ASME Sec. III Division 1	ASME Sec. III Division 1 TEMA "R"	ASME Sec. III Division 1	ASME Sec. III Division 1 TEMA "R"
B	B	ACI 318	ISA Standards; NEC (designed to fail on preferred mode)	ASME Sec. VIII Division 1	ASME Sec. VIII Division 1	ANSI B16.5; ANSI B31.3	ANSI B31.3	ASME Sec. VIII Division 1 TEMA "R"
C	C	NYS Building Code	ISA Standards; NEC	ASME Sec. VIII Division 1 (or API 620 and API 2000 for large, low pressure tanks)	API-610 (or manufacturer's standard)	ANSI B16.5; ANSI B31.3	ANSI B31.3	ASME Sec. VIII Division 1 TEMA "C"
N	N	NYS Building Code	ISA Standards; NEC	Manufacturer's Standard	Manufacturer's Standard	Manufacturer's Standard	Manufacturer's Standard	Manufacturer's Standard

Evaluation: The fundamental concepts of the approach to design for the WVDP represent sound engineering practice and are based on methodology used historically for facilities with similar or greater hazards. The design philosophy for the VF is one that emphasizes the confinement of potential radiological releases. The outermost level of confinement is provided by passive confinement structures and components whose continued function under all but incredible conditions is assured by design (10 CFR Part 50, Appendix A, Criteria 2 and 16). Multiple barriers of confinement are provided to minimize dependence on any single barrier (10 CFR Part 50, Criteria Category II, Protection by Multiple Fission Product Barriers). Redundancy and/or backup capability are included in the design for high reliability (10 CFR Part 50, Appendix A, Criterion 21). For ventilation of radiological areas, airflow is controlled so that airborne radiological contaminants are directed from areas of lesser contamination to areas of greater contamination. This "cascading pressure" design feature has the effect of controlling doses due to airborne radiological materials [10 CFR Part 72, §72.126(a)].

The graded approach to assigning safety classification and quality levels has previously been found acceptable by NRC during the review of the site SAR. The graded approach originates from ASME NQA-1 (American Society of Mechanical Engineers, 1989), Basic Requirement 2. ASME NQA-1 is widely recognized as the basic nuclear QA programs standard.

With respect to radiological hazards, limitation of Safety Class B to those components that provide primary confinement (e.g., concrete hot cell, transfer tunnel, VF shielded viewing windows, etc.) and VC HVAC (e.g., duct-cell exhaust system, primary HEPA filter bank, etc.) is consistent with the safety classification criteria given in Table 2 of WVNS-204.

The choice of various industry standards that were chosen to apply to different components and structures for each safety class and quality level, as they appear in WVNS-204, appears to be appropriate and commensurate with the corresponding safety class and quality level. The policies and guidance given in QM-2 appear to be logical and consistent with ASME-NQA-1 (American Society of Mechanical Engineers, 1989). Procedures and guidance for design control in QM-3 reflect good design practice and a degree of guidance adequate to control design quality.

The definition of the margin of safety should be changed in future revisions of WVNS-SAR-003 to more accurately reflect the intent that it represents the factor by which the DBE or DBT loads can be multiplied before failure occurs.

2.1.2.2 Seismic Design Considerations

The seismic design considerations for the VF are based on the following statement given in UCRL-15910 (Kennedy et al., 1990). "Adequacy of critical and non-critical structures to withstand vibratory ground motion shall be verified, according to DOE Order 6430.1 (U.S. Department of Energy, 1983), using suitable dynamic analysis techniques, except where the static response technique of the UBC can be shown to provide a conservative estimation. The maximum loads determined by dynamic analysis

are then combined with dead load and other live load." An overview of the seismic analysis steps is given in Figure 2-4 [from LA-210249-MS (Elder et al., 1986)].

In the seismic re-evaluation, consideration was given to the overall response of the VF as well as detailed calculations for specific equipment and components. The seismic design of the overall facility is based on a soil-structure interaction analysis used to determine the global response of the facility (Gates, 1993; Raytheon, 1995). Excitation for these models was based on the time histories developed to envelope the site-specific response spectra. Results from this analysis were then used to develop elevated response spectra, at specific locations in the VF, for subsequent analysis of specific equipment and components. Samples of these analyses of specific equipment and components were reviewed as part of the work performed under this program.

The seismic design of the overall facility is based on dynamic analysis of linear elastic soil-structure models of the primary confinement cells. The initial analysis was based on a simplified 3D beam model of the structures with springs and dampers used to represent the soil characteristics (Gates 1993). The beam elements and added mass were used to model the overall dynamic characteristics of the facility. The damping values used in the original 3D stick model were 7 percent for the structural elements and 20 percent for the soil to account for both material (hysteretic) and radiational (wave propagation) damping. The value of damping used for the structural elements is consistent with the damping values given in RG 1.61 (Nuclear Regulatory Commission, 1973) for reinforced concrete at the DBE level. A question that arose early in the review concerned the values used for soil damping in the system and the resulting composite damping. Initially, it was felt that 20 percent for soil damping was excessive because of the small strains that would be induced in the soil due to 0.10 PGA excitation.

To accurately define the strain field in the soil surrounding the foundation, it was necessary to develop a full 3D solids model of the system including the soil and foundation structure (Raytheon, 1995). The analysis used time-history motions for three simultaneous orthogonal directions to compute the earthquake response of the building structure. The time-history earthquake input motions to the model were synthetically generated to envelope the design basis response spectra in accordance with RG 1.60 (Nuclear Regulatory Commission, 1977a). The damping properties of the model were based on RG 1.61 (Nuclear Regulatory Commission, 1973). Spatial attenuation of energy from soil-structure interaction was accounted for in the model. Results of this type of soil-structure model were then used for subsequent simplified analysis to verify the results (Rowland, 1995). The review process used by Dames & Moore utilized a composite modal damping of 15 percent, based on the relative strain energy in the elements.

> *Evaluation: Based on the detailed soil-structure interaction analysis performed and information provided in the February 1995 meeting (Rowland, 1995), the values used for both soil and composite damping for the VF are acceptable. The soil-structure interaction analysis of the overall response of the VF have been performed in accordance with the state-of-the-art procedures.*

The results of this overall dynamic analysis provided forces and floor motions at the various levels of the structure that were used in the design of the confinement structure (walls, roof, floors) and in the fundamental performance and anchorage requirements for equipment (primary filters, coolers, melter supports, etc.) within the structure designed for the induced loads resulting from the DBE. The floor-design, response-spectra method and the time-history methods were used in analysis of component adequacy. A basic approach to these methods is discussed in RG 1.122 (Nuclear Regulatory Commission, 1978a).

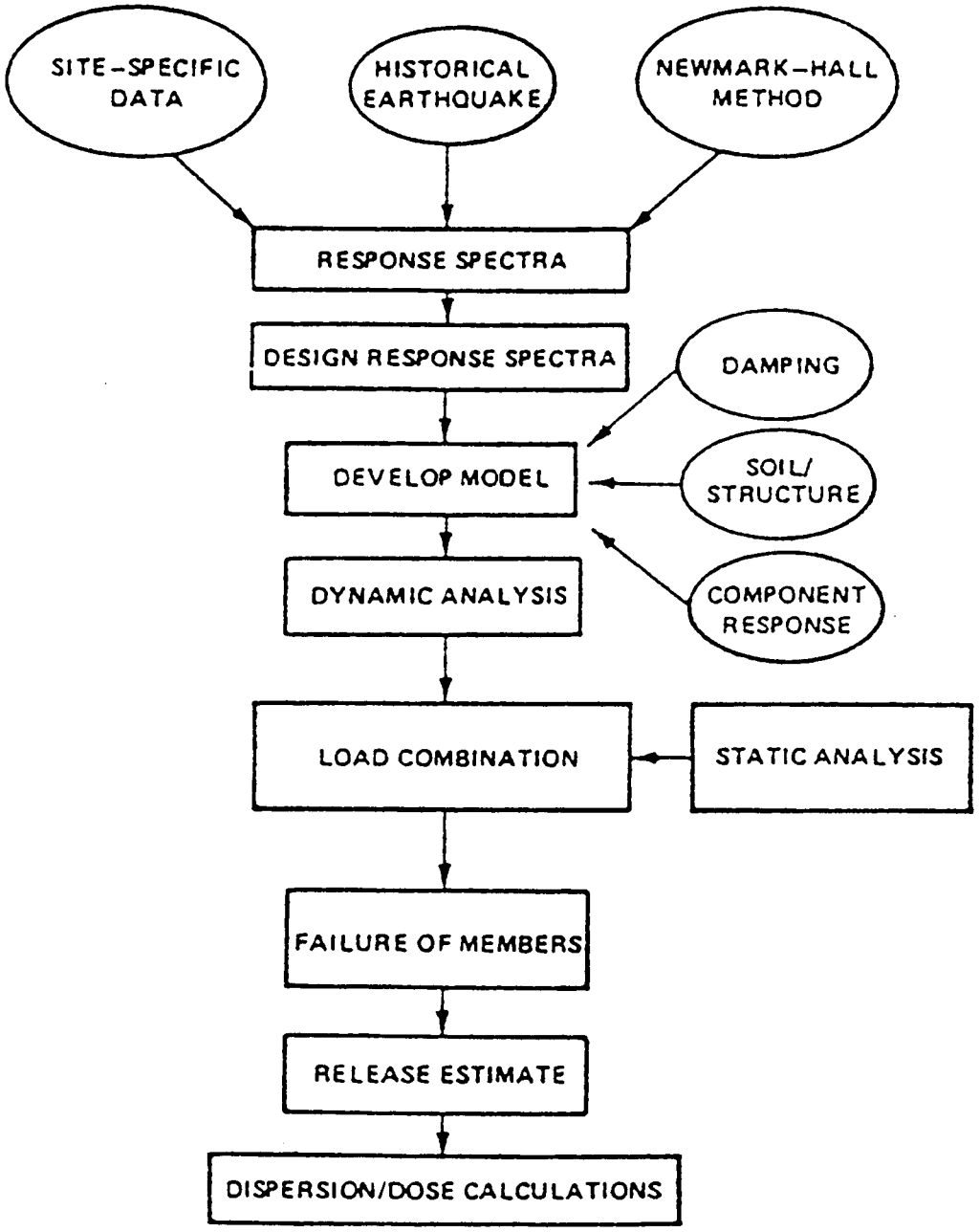


Figure 2-4. Overview of earthquake analysis steps (Elder, 1986)

A conservative approach to the seismic design is to perform a simplified equivalent static analysis based on the total weight of the structure and the peak acceleration of the DBE shock spectra. This procedure can be utilized for structures and equipment that have a first mode frequency greater than the cutoff frequency for the elevated portion of the response spectra. This corresponds to 33 Hz for the horizontal RG 1.60 (Nuclear Regulatory Commission, 1977a) spectra.

The static procedure can also be applied to structures whose first mode is less than the cutoff frequency for the elevated portion of the response spectra. In this case, the equivalent static load for a given mode is equal to the weight of the structure times a factor including the peak acceleration and an amplification factor, taking into account damping of the mode in question. For a single mode, this equivalent static load is added directly to all other loads to determine the margin of safety. If multiple modes exist, several different modal combination procedures can be applied.

For complex structures and equipment with modes within the elevated region of the response spectra, it is advisable to perform a linear elastic finite element analysis (FEA). The structure or equipment is first modeled using finite elements to define the appropriate geometry mass, stiffness, and damping characteristics. These models can range in complexity from detailed 3D solid models to simpler 3D beam and truss models. For static analysis, after defining the structure, loading, and restraints, the response of the structure can be calculated. For dynamic analysis, an eigenvalue analysis is first performed to determine the natural frequencies and mode shapes. These results can then be used to determine the dynamic response under a variety of loading conditions.

Dynamic analysis procedures for determination of the structural response of critical elements to earthquake events can be based on a time-history solution or a response-spectra solution using modal superposition. The analysis for this program utilized a time-history solution based on a single set of three statistically independent signals (two horizontal and one vertical directions). This excitation was applied to FEA models of various critical structures and equipment.

There were several general concerns associated with the seismic analysis procedures utilized. A single set of three statistically independent time histories was used to calculate the dynamic response of the system. This is appropriate when the assumption of linear elastic response is used, as was done for the majority of the structures and components in the VF.

To further verify the validity of the input time histories, the duration of the strong motion portion of the event and the shape of the power spectral density (PSD) of the signal were shown to be in accordance with standard engineering practice. The duration of the strong motion portion of the event was related to the magnitude of the event [ASCE 4-86 (American Society of Civil Engineers, 1986)]. The PSD of the signal was in accordance with the PSD for the RG 1.60 spectra (Nuclear Regulatory Commission, 1977a).

Analyses show that all major process components in the VC pit have a seismic design capacity sufficient to prevent their ultimate failure or collapse from extreme environmental loading in excess of the DBE. Furthermore, the three tanks will not pound together causing them to lose their structural integrity. However, they may lose their functionality during a DBE. Continued operation of the VC HVAC system during and after a DBE event is expected because the HVAC CR, controls, blowers, filter units, uninterruptible power supply (UPS), and associated standby diesel generator are DBE qualified.

Evaluation: The basic procedures used in the seismic analysis of the individual components and equipment are in accordance with standard engineering practice.

It should be noted that FEA procedures are appropriate where the functionality of the structure or equipment can be defined in terms of the response motions and resulting stresses in the structure. If operability is required, it is often easier to perform testing to verify functionality under the dynamic loading. The basic approach of the equipment qualification program is in accordance with established procedures for NPP equipment, Institute of Electrical and Electronics Engineers, Inc. (IEEE)-344 (Institute of Electrical and Electronics Engineers, Inc., 1987). Typically, a test program includes subjecting the equipment to time histories that envelope the required response spectra with a margin applied, typically 10 percent, over the entire frequency range. The excitation is applied in three directions, either three, two, or one axis at a time. The functionality of the equipment is checked before, during, and after the event, as required. If the equipment functions properly under all conditions, it is assumed to be qualified. A number of components were qualified by testing. No detailed review of the test reports was done.

Evaluation: No CNWRA review of any test results was performed.

Structures that are not required to confine radioactive or hazardous material have been designed to the New York State Code Manual for the State Building Construction Code, and incorporated seismic considerations from the UBC (International Conference of Building Officials, 1988). These structures are not required to survive extreme environmental loads (natural hazard phenomena) without loss of function. However, these structures should survive without collapse to satisfy minimum life safety requirements under less severe environmental loading. These criteria apply to both new construction and modifications to existing structures, per WVNS-SAR-003.

After design was completed, an independent assessment of the structural integrity of the confinement barriers was performed by Dames & Moore. This assessment identified margins of safety and modes of failure under extreme environmental loading beyond the DBE and DBT. Safety margins reported represent the factor by which the loads produced by the DBE or DBT can be multiplied before ultimate failure of the component will occur.

2.1.2.3 Tornado and Tornado Missiles Design Considerations

The structural response to wind loading as well as the penetration potential due to tornado-borne missiles were considered in WVNS-SAR-003. Tornado resistance calculations consider combined loads resulting from rotational plus translation wind speed, rate of pressure drop, and missiles. Wind loading and pressure differential are of secondary concern for the major structural elements where other loadings control, but are critical for the design of the HVAC system. Analysis of the response of the system to tornado and the maximum wind loading was based on the procedures of ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988). Structural adequacy for the facility with respect to the DBT is based on a design in accordance with an annual probability of exceedance of 10^{-6} yr.

The penetration resistance of the primary structural elements was based principally on comparison to published data for concrete, steel, and soil barriers. Some analysis of the doors was performed to consider rebound. The methodology for tornado missile load analysis on the special doors is based on a two-step approach: (i) equivalent static, or (ii) dynamic response. Analysis done in support

of WVNS-SAR-003 used the equivalent static approach of testing to develop margins of safety (Gates, 1992). For the shield windows, the approach taken was to assume that penetration did occur and to determine the level of leakage. If the leakage rate was below allowable levels, then the design was considered to be acceptable. This procedure was discussed in detail in Section 4 of CNWRA 93-007 (Pomerening et al., 1993), to which the reader is referred for discussion of details associated with the tornado and tornado missiles design considerations.

Evaluation: The basic design procedures for tornado and tornado missiles design considerations used in support of WVNS-SAR-003 are in accordance with standard engineering practice [ANSI/ASCE 7-88 (American National Standards Institute/American Society of Civil Engineers, 1988)].

2.1.2.4 Passive Confinement Systems

Safety features have been engineered into the design of the VF to minimize the potential environmental risks of the release of radioactivity due to loss of confinement. The safety features included a system of confinement barriers that function both during normal vitrification operations and during accident conditions or extreme environmental accident conditions. By definition, a confinement barrier serves to restrain, but not necessarily totally contain, the contents within it. A structure required to confine radioactive or hazardous material that could affect the health and safety of the public or site personnel shall be designed to withstand the effects of natural hazards and still perform its safety function(s) and confine the radioactive or hazardous material to acceptable levels.

A concept associated with the passive confinement systems in the VF is the use of multiple confinement barriers and systems in support of the defense-in-depth aspects of the design of the VF. Details of the multiple confinement barriers systems are given in the evaluation of specific structures, systems, and components in Subsection 2.1.3.

The hazard and accident analysis given in Chapter 9 of WVNS-SAR-003 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 VC, crane maintenance room, and transfer tunnel walls, floors, doors, roofs, shield windows, hatches, and penetrations.

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 SFR, HVAC CR, DGR, and the associated controls and equipment of these rooms are designed to withstand extreme natural phenomena events.

Radiation protective features basic to the design of the VF are dedicated to maintaining radiation doses to members of the general public and the work force ALARA. Effective control of radiation doses depends primarily on the following design features that provide shielding from sources of radiation: (i) remote operations and maintenance, (ii) confinement of radioactive materials within the process vessels and piping, (iii) proper ventilation, (iv) effluent control, and (v) monitoring and surveillance to verify design controls. These physical design features, together with strict adherence to operational requirements presented in WVDP-0101, provide effective radiation control.

Evaluation: The use of passive confinement systems to mitigate the effects of radiological releases during accident conditions is in conformance with standard engineering practice. Multiple barriers of passive components are also consistent with standard engineering practice. It should be noted that during normal operation, active confinement systems are necessary to ensure that the cumulative effects of radiological releases are below allowable levels.

2.1.2.5 Active Confinement Structures, Systems, and Components

Safety features have been engineered into the design of the VF to minimize the potential environmental risks of the release of radioactivity due to loss of confinement. Systems required to confine radioactive or hazardous material that could affect the health and safety of the public or site personnel must be designed to withstand the effects of normal operating and severe environmental conditions, still perform its safety function(s), and confine the radioactive or hazardous material to acceptable levels. It must also be designed to withstand extreme environmental conditions without affecting the performance of the passive confinement systems.

Details of the various active confinement systems or components are contained in Subsection 2.1.3, especially 2.1.3.7 and 2.1.3.8.

Evaluation: The use of active confinement systems to mitigate the effects of radiological releases during normal operation and severe environmental conditions is in conformance with standard engineering practice. The use of active confinement systems during normal operation is necessary to ensure that the cumulative effects of radiological releases are below allowable levels.

2.1.3 Evaluation of Specific Structures, Systems, and Components

This section contains an evaluation of specific structures, systems, and components, with respect to their compliance with the WVDP design philosophy, and their ability to withstand design basis events such that radiation doses to the public and to operating personnel are adequately controlled. Margins of safety were obtained from WVNS-SAR-003. Information in this document is based on the most recent results (Rowland, 1995) and may not be reflected in the WVNS-SAR-003 reviewed in this SER.

2.1.3.1 High-Level Waste Transfer System

The HLWTS described in WVNS-SAR-003 is limited to those components through which HLW is transferred from Tank 8D-2 to the VC confinement boundary. An overview of the HLWTS is shown in Figure 2-5. Components included are the Pump Pits 8Q-2, Diversion Pit 8Q-5, and the transfer trench and its associated piping. The HLWTS covered by WVNS-SAR-003 does not include the tank farm, where existing tanks with HLW are located. Tank 8D-2, which is within the tank farm, is the origin of the waste stream. The Margin of Safety Summary for the HLWTS Confinement Barrier is in Table C.5.2.3-3 of WVNS-SAR-003, but this table also includes components, such as some associated with the tank farm.

The reinforced concrete transfer trench contains piping for transfer of liquid HLW to and from the waste tanks and the VC. Piping inside the trench is double-walled, welded SS, that is instrumented

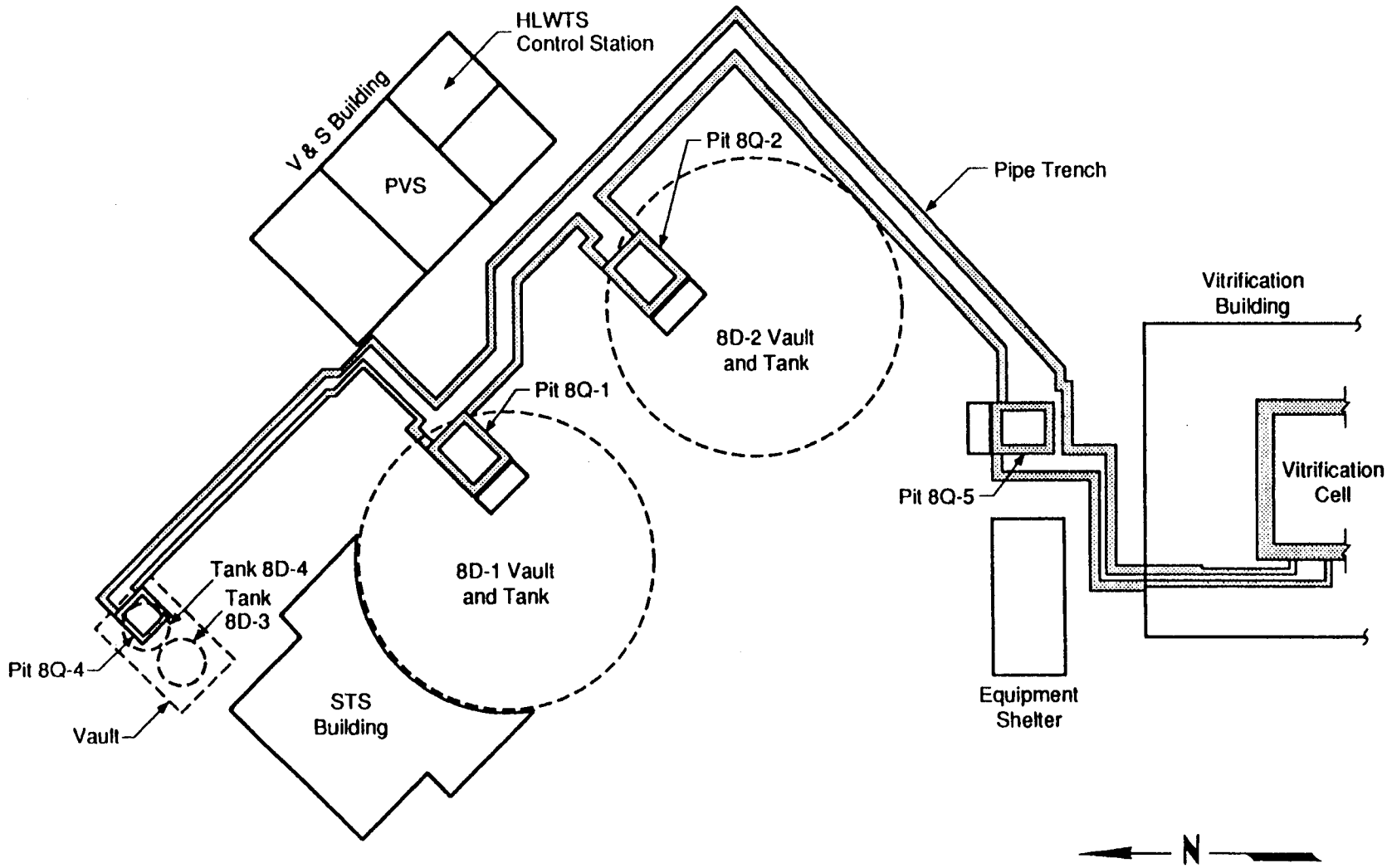


Figure 2-5. Overview of the high-level waste transfer system (Dames & Moore, 1994b)

between walls with conductivity-probe leak detectors. The double-walled piping provides confinement, while the reinforced concrete of the trench provides radiation shielding but not confinement. Piping runs within the trench are supported with carbon steel supports such that a gradient in the line allows gravity draining back to low points at Pits 8Q-2 and 8Q-5, from which any leakage gravity drains back to Tank 8D-2.

The transfer pump, located in Pump Pit 8Q-2, discharges liquid HLW through a single-wall pipe (jumper) that transitions at the pump pit/transfer trench wall into the double-walled SS piping typical of the transfer trench. Potential leaks from the jumper drain back to Pump Pit 8Q-2 and then back to the 8D-2 tank below. Each pump pit is lined with SS for secondary containment of potential leaks, and any such leakage is drained back to the tank below. Conductivity probes are installed in the pits to detect leaks, and the associated alarm is routed to the Plant Ventilation System (PVS) Building where the pump operators are stationed. Pump operators respond to the alarm by shutting down pump operations. Leak detectors (conductivity probes) in the double-walled transfer pipe are instrumented to electronic interlocks that prevent pump operation and HLW transfer if a leak is detected. The volume of liquid HLW transferred in a batch to the CFMT (3,400 gal.) is preset via the pump controller, which automatically shuts down the pump when that volume has been transferred. Transfer lines are flushed between batches to prevent solids buildup.

The PHA (Table C.9.3-1 of WVNS-SAR-003) indicates that operability of leak detectors in pump pits and the transfer trench is to be verified, but the text of WVNS-SAR-003 does not discuss when or how this is to be accomplished.

The portion of the HLW transfer trench nearest the VB is covered with steel trench covers instead of the concrete trench covers that are used for the rest of the trench. WVNS-SAR-003 does not address any difference in hazards or maintenance procedures for the steel-covered section. Note that no independent review of the shielding requirements of any elements was performed. Dames & Moore (1994a) indicates that inside the VF, the trench is covered with steel plates to provide radiation protection to workers in the operating aisles of the VF.

Valves within the Diversion Pit 8Q-5 are operated through sealed holes through the concrete cover so that HLW can be routed from Tanks 8D-2 to the CFMT, and out-of-specification waste solutions can be returned from the VC to the tank farm. Return lines from the waste header and condensate return lines drain by gravity and are hard-piped (not valved) through an adjacent chamber of Pit 8Q-5.

Ventilation for the pump and diversion pits is provided by the waste tank farm ventilation system (WTFVS). No ventilation was provided for the HLW Transfer Trench, and this was rationalized in WVNS-SAR-003 by noting that process liquids are transferred through double-walled piping that drains to the floor of one of the pits.

Pump Pits 8Q-1 (over the 8D-1 tank) and 8Q-4 (over the 8D-4 tank) are not adequately discussed in the WVNS-SAR-003, and neither are the in-ground pipes for transfer between these tanks and the vitrification system. Future revisions to WVNS-SAR-003 should indicate which DOE-approved safety documentation covers these pits and transfer pipes.

Margin of Safety

The margin of safety against the DBE for the HLW reinforced concrete trench is given in Table C.5.2.3-3 of WVNS-SAR-003 as greater than 7×DBE. The margin of safety for the double-walled steel piping is greater than 4×DBE, while that of the pipe support within the trench is greater than 2×DBE. Single-walled SS jumpers within the pits have a margin of safety greater than 3×DBE, per Table C.5.2.3-3 of the WVNS-SAR-003. The margin of safety for the connecting PUREX couplers is listed in the table as greater than 1×DBE, which is the lowest of the margins listed. Potential failure is mitigated by the SS liner of the pit, from which any leak would gravity-drain to one of the HLW tanks.

The margin of safety against rupture due to the DBE for the buried double-walled SS pipe is given in Table C.5.2.3-3 of WVNS-SAR-003 as greater than 1.0×DBE although Dames & Moore (1994b) indicates the margin to be greater than 4.0×DBE, based on the seismic re-evaluation. These are gravity flow return lines for materials from the VF, acidic waste header material, and condensate from the CFMT. They have a heavy concrete slab on top for radiation shielding and tornado missile impact protection.

The margin of safety for HLWTS components listed in Table C.5.2.3-3 against the DBT is not less than 7×DBT, based on penetration by a tornado-driven missile. The margin against the DBT for the steel-covered portion of the trench adjacent to the VB is not listed in the table.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

HLWTS design features that provide multiple levels of confinement include the following: (i) double-walled piping inside the trench, (ii) SS lining for each pump pit for secondary containment of potential leaks; and (iii) gravity-drain from pump pits to HLW tanks. Elements of the design that reflect the application of the concept of ALARA include installation of conductivity probes between walls of the double-walled SS transfer pipe, electronic interlocks that prevent pump operation and HLW transfer if a leak is detected between the two walls of the transfer pipe, the installation of conductivity probes for leak detection in the pump pits and the diversion pit, automatic control of batch volume transferred from Tank 8D-2 to the CFMT, and the incorporation of gradients in various transfer lines to allow gravity draining back to low points. The associated alarm is routed to the PVS Building where the pump operators are stationed.

Evaluation: The population of structures, systems, and components considered in the WVNS-SAR-003 for the HLWTS includes most of those that are important to active and passive confinement. Missing from the WVNS-SAR-003 are discussions on the safety aspects of (i) Pump Pits 8Q-1 and 8Q-4; (ii) the buried double-walled steel pipe from those two pits; (iii) the steel-covered portion of the HLW pipe trench, and (iv) tests for functionality of leak detection in pump pits and those in the transfer trench. Future revisions of WVNS-SAR-003 should either provide such discussions or refer the reader to them elsewhere. The scenarios considered in analysis of margins of safety for the structures, systems, and components of the HLWTS are appropriate and complete. The margins of safety for the structures, systems, and components of the HLWTS indicate that none should fail under design basis loads. For those passive HLWTS components most important to confinement (pump pits and diversion pit, pipe trench), margins of safety are not less than 2 except for the PUREX couplers, from which leaks gravity drain back to tanks. There is some variation between certain margins of safety given

in WVNS-SAR-003, Dames & Moore (1994a), and Dames & Moore (1994b). No indication of the reason for the differences is given in WVNS-SAR-003, and it is assumed that the values resulting from seismic re-evaluation (Dames & Moore, 1994b) are most up to date. Analysis of the HLWTS is based on the soil-structure interaction analysis (Raytheon, 1995) and independent Dames & Moore calculations (Dames & Moore, 1994a; 1994b) and is in conformance with standard engineering practice.

2.1.3.2 Cold Chemical System

Description

The cold chemical system (CCS) includes several tanks and pumps that are used in the mixing and transportation of the various chemicals and glass formers needed for the VP. The CCS is housed in a building 10.4 m wide and 17.2 m long. The building and its contents are not part of the passive or active confinement structure of the VF. As such, they are not required to be functional during any extreme natural hazards. The building houses nine tanks: three slurry tanks, one drain tank, and five process tanks. The CCB is a nonradiological area, and the main concern is the potential for chemical contamination. The CCB HVAC system is used mainly to maintain a suitable thermal and an adequate airflow environment for the personnel. The building HVAC system maintains a slight negative pressure with respect to the outside. However, the CCB CR has a slight positive pressure. The HVAC system in the CCB is independent of the VC HVAC. The potential for dusts and vapors in the CCB is present in the scale room area. A dust collection hood with an air filtration system in the scale room minimizes the chemical contamination in the area. Chemical spills in the building are collected by the cold chemical sump and stored in the cold chemical drain tank for future off-site disposal. A complete summary of the PHA for the CCS is given in Table C.9.3-5 of the WVNS-SAR-003. None of the indicated hazards are radiological in nature.

Margin of Safety

The CCS components are not part of the confinement system for the VF, and specific margins against design basis seismic events were not calculated. However, all the process and drain tanks, and the associated piping structures, are designed and fabricated in accordance with ASME Boiler/Pressure Vessel Code Section VIII, Division I, that provides the acceptable operational margins of safety.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

There are no special considerations in the CCS required to mitigate any radiological releases since radiological hazards are not present.

Evaluation: The control for the operation of the tanks in the Cold Chemical Facility is separate from the control for the VC. The operations are sometimes unmanned and unsupervised in the CCB. An alarm system and a control panel to switch on equipment and valves exists in the building. Also, an alarm sounds in the VC CR from the CCB, if the alarm from the CCB is unattended. However, there are no controls in the VC CR to implement any action, and the possibility exists for unplanned transfers or shut-offs of cold chemicals to the VC. It is recommended that the possibility of this situation be addressed as part of the operational readiness review.

2.1.3.3 Confinement Structures

Description

The primary confinement structures for the VF consist of reinforced concrete structures. Some are new construction while others are modifications to existing structures. The major elements are described briefly in the following. These barriers have various integral enclosures and components, including special doors, shield windows, pipe penetrations, hatches, trench covers, etc. These components have been engineered to maintain their integrity as confinement barriers. Where possible, redundancy of barriers has been incorporated in the design so that radiological releases to the environment would require the failure of more than one barrier. Refer to WVNS-SAR-003 and supporting documentation for details of the design and construction of the facility. The engineered confinement barrier structures relied on during accident scenarios, including natural phenomena-induced accident scenarios, are described in the following sections.

Vitrification Cell

The VP of converting the liquid HLW to a glass form is carried out in the VC. The VC is the primary passive confinement system for the HLW during the VP. It is a reinforced concrete structure and includes special doors, shield windows, pipe penetrations, etc. The overall dimensions of the VC are approximately 38 ft (E-W direction) by 64 ft (N-S direction), as taken from plan drawings in WVNS-SAR-003. The major portion of the floor is at an elevation of 100 ft and the cell has a ceiling height of approximately 145 ft. At the north end of the cell is a pit that contains the three major process tanks and melter. The pit extends 26 ft in the N-S direction and has a floor at elevation 86 ft. Other sections of the VC contain facilities for handling the canisters (including the canister turntable, weld station, and decontamination station), HVAC systems, off-gas systems, and process control and monitoring systems. The thickness of the reinforced concrete structures varies throughout the cell and is a nominal 3 ft. The walls of the VC are covered with a SS liner up to an elevation of 122 ft. This liner acts as a barrier to any liquids that may spill. The remainder of the reinforced concrete cell is painted with a special paint for radiation control and decontamination. Careful attention was paid to the design of the special doors, shield windows, pipe penetrations, and other penetrations to ensure they would not compromise the confinement barrier. There are two viewing windows on the north wall and three viewing windows on the east wall of the VC. There is a hatch on the roof of the VC to allow installation of components and maintenance as required. Equipment and components installed in the VC are discussed in detail in the following sections of this document. Refer to the WVNS-SAR-003 and supporting documentation for details on the design and construction of the VC. The PHA for the VC is contained in Table C.9.3.3-2 of WVNS-SAR-003, and it includes both airborne and contained radiological hazards. The identified hazards also consider the potential for fire.

Crane Maintenance Room

The CMR is located on the south end of the VC aligned with the east wall. The CMR is included as part of the confinement structure because it communicates with the VC environment during crane maintenance. The CMR is located above the transfer tunnel and is utilized for maintenance of the cranes used within the VC. The overall dimensions of the CMR are approximately 38 ft (E-W direction) by 36 ft (N-S direction), as taken from plan drawings in WVNS-SAR-003. The floor is at an elevation of 124 ft and the ceiling is at approximately 145 ft. Special Door #2 allows access between the CMR and the VC. This door moves vertically during opening into a reinforced concrete pocket located above the

CMR. It should be noted that during normal operation this door will remain closed, providing some isolation between the CMR and VC. Door # 7 allows access to the CMR from outside the confinement barrier. There is a hatch cover on the room of the CMR to allow for installation of and access to the cranes.

Transfer Tunnel

The transfer tunnel is included as part of the confinement structure because it communicates with the VC environment during transfer of canisters to storage. The canisters are transferred through the tunnel with a transfer cart capable of holding four canisters. The VC and transfer tunnel were built to mate with the existing EDR and CPC (now called HLWIS). For this reason, the transfer tunnel is designed and built to be seismically "decoupled" from the EDR and HLWIS. The transfer tunnel is located directly below the CMR and is approximately 19 ft (E-W direction) by 36 ft (N-S direction) as taken from plan drawings in WVNS-SAR-003. The floor is at an elevation of 100 ft and the ceiling is at approximately 124 ft. The transfer tunnel Door #1 allows access between the VC and the EDR. This door moves horizontally into a reinforced concrete pocket on the east side of the facility. As previously noted, during normal operation this door will remain closed, providing some isolation between the transfer tunnel and the VC. Door #8 is used for access between the transfer tunnel and the HLWIS. The PHA for the transfer tunnel is contained in Table C.9.3.3-3. For confinement consideration, one failure scenario is related to failure of the shield doors.

Secondary Filter Room

The SFR is necessary to maintain the cell air filtration function for active confinement. VC air is drawn into the SFR through two 24-in.-diameter ducts in the south wall of the VC. The air is then further processed prior to release to the atmosphere. The SFR is located west of the transfer tunnel along the south wall of the VC. The SFR is an L-shaped structure within a rectangular structure that is approximately 41 ft (E-W direction) by 36 ft (N-S direction), as taken from plan drawings in WVNS-SAR-003. The floor is at an elevation of 100 ft, and the ceiling is at approximately 124 ft. Special Door #6 allows access between the SFR and the EDR. Special Door #4 allows access to the SFR from outside the confinement barrier.

Diesel Generator Room

The DGR is designed to withstand natural phenomena events so that backup electrical power would be available to run the active HVAC confinement system components. It contains the backup diesel generator and associated controls. The DGR is located in the northwest corner of the rectangular structure that contains the SFR. The DGR is approximately 17 ft (E-W direction) by 18 ft (N-S direction) as taken from plan drawings in WVNS-SAR-003. Access to the DGR is through a door into the SFR.

HVAC Control Room

The HVAC CR is necessary to maintain the cell air filtration function and contains the equipment and controls necessary to operate the VC HVAC. The HVAC CR is located above the DGR and SFR and is accessed from outside confinement through Special Door #5. The HVAC CR is approximately 24 ft (E-W direction) by 36 ft (N-S direction) as taken from plan drawings in WVNS-SAR-003.

Equipment Decontamination Room

The EDR is an existing structure that was modified to accommodate functions of the VP. Structures such as the EDR are not required to withstand the DBE, since their failure would not result in significant environmental releases. Separation between the EDR and the new VC construction is a 3-in. seismic joint containing Rodofoam II. The EDR is approximately 49 ft (E-W direction) by 39 ft (N-S direction) as taken from plan drawings in WVNS-SAR-003.

High-Level Waste Interim Storage

The HLWIS is an existing structure (CPC) that was modified to accommodate functions of the VP. Structures such as the HLWIS are not required to withstand the DBE, since their failure would not result in significant environmental releases. The major portion of the HLWIS is approximately 22 ft (E-W direction) by 93 ft (N-S direction) as taken from plan drawings in WVNS-SAR-003. There is an additional short section that interfaces to the EDR. The PHA for the HLWIS is given in Table C.9.3.3-4, and it includes failure due to damage to the reinforced concrete structures.

Analysis of the confinement structure response included the roof, walls, mat, soil, special doors, hatch, and shield windows. For the roof, walls, and mat, the majority of analysis was based on strength of materials approach under the various loading conditions. Response of the soil was addressed in the soil-structure interaction analysis. The structural design review and integrity assessment of the eight special doors of the VF that function as critical elements of the primary confinement barrier system were part of the Dames & Moore review. Three separate methods of investigation were used to assess the structural integrity of the shield doors under extreme environmental conditions. These methods included analytical methods, experimental methods, and engineering judgment. A comprehensive list of failure modes for the doors was developed (Gates, 1992). Operability and/or leak prevention is not a requirement for the special doors, only that they remain in place. For the hatches, uplift was the primary concern. The primary concern for the shield windows was penetration during the tornado events.

Margin of Safety

Analysis of the primary confinement structure response included the roof, walls, mat, soil, special doors, hatch, and shield windows. Results of the margins assessment for the primary civil structures are:

- Roof, Margin $> 3.5 \times$DBE
- 26-inch wall, Margin $> 4.5 \times$DBE
- 48-inch wall, Margin $> 3.5 \times$DBE
- Mat foundation, Margin $> 6.5 \times$DBE
- Foundation soil, Margin $> 8.7 \times$DBE

The failure mode for the cell roof and walls is yield of the reinforcing steel, resulting in a plastic hinge. Indications are that cracking of the roof slab and the top portion of the walls of the VF could occur during an earthquake of magnitude less than the DBE, when out-of-plane bending is

combined with thermal stresses. The assumption made in WVNS-SAR-003 was that cracking is not considered a failure because there will be no potential for release of radiological materials since cracking will not propagate through the thickness of the structure (Dames & Moore, 1994c). For the foundation mat, the failure mode was uplift, while the soils failure was based on cracking. The major structural elements, including the roof, wall, and mat, have margins of safety greater than 3.5×DBE. This is not the controlling factor for design of these structures, which is the combined dead and thermal loading.

> *Evaluation: A review of the fundamental frequencies of the civil structures, provided by Dames & Moore, indicate the lowest mode for the reinforced concrete vault is 7.0 Hz for one of the lateral directions and represents rigid body motion of the structure. Therefore the analysis techniques used to develop the margins of safety are appropriate. Each of these margins of safety are acceptable based on the assumed loading, damping, and analysis procedures. Reasonable assumptions have been used in calculating the consequences of tornado missiles striking the windows. The conclusion that there will be no releases resulting from the missiles is acceptable based on the evaluation that the missiles do not directly penetrate any of the in-cell tanks or piping containing HLW.*

In addition to structural failure, the potential for contact between the VF cell and the EDR of the existing Nuclear Fuel Reprocessing Plant was calculated. The separation between the VF and the EDR during the seismic events is based on modeling the response of the building under the influence of traveling seismic waves combined with the dynamic response of the buildings. This analysis showed a maximum of 0.7 in. closure for a total gap of 3 in. for an uncoupled model with 15 percent composite damping. For a coupled model, the maximum closure was 0.8 in. The resulting margins of safety are acceptable. Analysis on the influence of the dynamic characteristics of the Rodofoam was performed and found to be insignificant.

> *Evaluation: The analysis techniques used to develop the margins of safety are in conformance with standard engineering practice. The margins of safety are acceptable based on the assumed loading and damping. Contact between the two structures is not credible.*

The behavior of the existing 160-ft reprocessing plant ventilation stack was analyzed under extreme environmental loads that include wind, tornado, and earthquake. The intent of the study was to realistically assess the collapse potential of the stack and the risk that such collapse might pose to the VF. Even if this failure were to occur, the possibility of any damage to the VF is remote.

> *Evaluation: The existing stack does not appear to pose any problem to the confinement barriers.*

The combined earthquake and dead load demand on the doors and their support hardware was based on using the peak response for the spectra provided in WVNS-EQ-264 and an equivalent static analysis. The critical margins of safety for the doors are:

- Transfer Tunnel Door #1, Margin > 2.1×DBE
- CMR Shield Door #2, Margin > 2.5×DBE

- CMR Personnel Door #7, Margin > 4.0×DBE

- Transfer Tunnel Door #8, Margin > 2.7×DBE

For these shield doors, the lowest frequencies are 5.2 Hz (Door #2 in the N-S direction) and 6.1 Hz (Door #8 in the N-S direction). All other frequencies are greater than 33 Hz, so the equivalent static methods used to assess the margins of safety are appropriate. In all cases, the peak response acceleration of the required response spectrum was used in the analysis, which is a conservative approach.

The special doors on the exterior of the facility must also be designed to resist tornado events but only need to stop tornado missiles and remain in place. The lowest margin of safety associated with the special doors is greater than 1.0×DBE based on yielding of the door leafs on Doors #4 and #5.

Evaluation: The special doors have margins of safety associated with both the earthquake and tornado events that are acceptable. Consideration of the appropriate failure modes have been included in the analysis.

The major consideration of the windows was penetration as a result of tornado-generated missiles. The worst case is the impact of the leaded glass windows with a 3-in.-diameter steel pipe traveling at 50 mph. For the shield windows, it appears that there is limited detailed test or analysis data for the response of such thick windows to missile impact. Details of the penetration analysis are contained in CNWRA 93-007. For the shield windows, the amount of leakage through the most credible hole was found to be acceptable by Dames & Moore (Gates et al., 1989). The margin of safety associated with the earthquake event was greater than 3.0×DBE.

Evaluation: The windows have margins of safety associated with both the earthquake and tornado events that are acceptable. Consideration of the appropriate failure modes have been included in the analysis.

The primary concern for the hatches on the VC and the CMR roof are uplift during the seismic events. The margin of safety for the cell roof hatch is greater than 6.0×DBE, while the margin of safety for the CMR roof hatch is greater than 10.0×DBE.

Evaluation: The hatches have margins of safety for the earthquake design basis event that are acceptable. Consideration of the appropriate failure modes have been included in the analysis.

Penetration failure was considered for relative motion of various portions of the penetrations as well as the potential for shearing due to impact of other structure and components. It should be noted that the majority of penetrations are designed with shut-off valves and other passive systems that will reduce the amount of release to acceptable levels. The lowest margin of safety for the five penetrations considered was greater than 2.5×DBE.

Evaluation: The penetrations have margins of safety for the earthquake design basis event that are acceptable. Consideration of the appropriate failure modes have been included in the analysis.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

The defense in depth concepts for the confinement systems are the use of multiple barriers and active/passive systems. For contained HLW, the first barrier is the process vessels and piping for the liquid phase and the canisters for the solid waste phase. If failure of the process vessels occurs, the liquid will be confined within the process pit of the VC. It will be confined by the SS liner and the reinforced concrete structures. Consideration of failure during the solid stage is considered insignificant because the waste is in a state that will not allow for release above allowable levels.

For potential releases associated with airborne contamination, the defense in depth is associated with the passive and active confinement systems. The passive systems are the confinement structures discussed in this section. The active systems are discussed in other sections of this document.

2.1.3.4 Concentrator Feed Make-up Tank, Melter Feed Hold Tank, Submerged Bed Scrubber

Description

The CFMT controls the feed make-up that is eventually sent to the SFCM via the MFHT. The CFMT is fed by the HLW from Tank 8D-2 and the effluent from the SBS. This mixture is sampled and analyzed to check for the proper concentration needed for the melter slurry. The cold chemicals and glass formers prepared in the CCS are also added in the CFMT. The PHA for these vessels is contained in Table C.9.3-2 of WVNS-SAR-003.

Margin of Safety

The three process tanks, namely CFMT, MFHT, and SBS are within the VC and are designed to withstand UBC Seismic Zone 3 forces. These tanks also carry an inventory of liquids. The UBC static analysis methodology does not adequately provide for the interactions among the liquid inventory, tank structure, and the tank support system. A subsequent dynamic analysis conducted by WVNS's contractor, Dames & Moore, provided a more detailed evaluation of the margins for failure for the tank and support structures. The new calculations show margins greater than 1.7 against ultimate failure or collapse of the tanks for a DBE (Rowland, 1995). It is expected that the structural integrity will be maintained for the tanks for DBE. However, the functionality may be lost for loads greater than the DBE where large displacements may sever connecting lines. The weakest component of the three tanks is the support system. A common support for the three tanks has a margin of safety of greater than 1.4×DBE. The support structure is made of A36 carbon steel I-beams. While both the CFMT and the SBS are constrained from movement in all directions, the MFHT allows for vertical uplift. For the MFHT, a nonlinear analysis was performed to account for large displacements during uplift of the tank. All other analyses were linear elastic analyses.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

The three tanks are located in a SS-lined pit within the VC. This pit provides additional protection against spillage and leaks. The drains can collect any contaminated fluids and assist in the confinement of the source of contamination. Also, the structural design of the tanks is such that, for DBE conditions, the tank components do not dislodge and affect any confinement barrier.

Evaluation: The detailed dynamic analysis conducted by WVNS for the three tanks and the support structure is appropriate and conforms to engineering practice. The lowest modes for the tanks are within the elevated portion of the design spectra, so the dynamic analysis is appropriate. The lowest margin calculated for the process tanks is greater than 1.4×DBE. Note that this margin is based on information given in the February 1995 meeting (Rowland, 1995) rather than in WVNS-SAR-003. This is acceptable because these are not part of the passive confinement system, and margins greater than 1.0×DBE are acceptable for the active confinement system.

2.1.3.5 Slurry-Fed Ceramic Melter

Description

The SFCM is key to the VP. The SFCM dries and melts the slurry feed from the MFHT and forms glass. In the melter, three Inconel 690 electrodes are operated in a controlled fashion to maintain uniform heating. The feed rate to the SFCM is in the range of 20 to 150 L/hr. The feed is made up of the HLW slurry, and glass formers (boron, silicon, and modifiers) are added as oxides or hydroxides. A cold cap, a solid crust, is maintained on top of the molten glass in the SFCM to provide the initial heat-up of a new batch of feed to begin drying it. As the cold cap heats the feed, gaseous and vapor components such as H_2O and NO_2 are formed. Gaseous components are handled by the process off-gas system. The cavity in the SFCM is made of a corrosion-resistant refractory while the shell is made of a corrosion-resistant Inconel material. Temperature in the melter ranges from 1,100 °C to 1,225 °C. The molten glass exits the main cavity into an overflow chamber at an average flow rate of 25 to 45 kg/hr and is then transferred to the HLW canisters for cooling. The PHA for the SFCM is contained in Table C.9.3-2 of WVNS-SAR-003.

Margin of Safety

The SFCM is supported by a steel truss frame at a height of 100.5 ft in the VC pit and is designed for possible removal in service. The SFCM is constrained from movement in all directions after allowing for thermal expansion and contractions. There are specially designed restraints necessary to ensure the structural integrity of the melter. From a detailed finite element dynamic analysis, the margin of safety was shown to be greater than 2.1×DBE. The melter itself is a very rigid structure when the brick lining and internal refractories are considered with the Inconel shell.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

The design and operation of the SFCM generally supports the defense-in-depth concepts. The inventory in the SFCM at any time is controlled. The development of a cold cap limits hydrogen explosion possibilities. The electrode selection and operations maintain uniform and controlled melt temperatures. The molten glass exiting the SFCM is controlled by an air-lift arrangement. This system prevents accidental spillage on the floor of the cell. The off-gases generated during the process are trapped and sent to the SBS in a closed loop arrangement.

Evaluation: The design and analysis of the SFCM and its support system are consistent with standard engineering practice. Because of the special supports, the lowest mode is 126 Hz, above the frequency in the response spectrum where the response acceleration is significantly amplified. The feed constituent controls and the

potential chemical reactions were developed during the Functional and Checkout Testing of Systems (FACTS) runs using nonradiological feeds. However, the basis of the various chemical processes in the melter have not been verified. Also, there are no data developed with radiological feeds. The balance between the amount of oxidant and reductant in the system is important to the quality of glass and the composition of the off-gases produced. It is recommended that a plan be outlined to develop the feed reduction index for the radioactive feed from data generated in the early part of the vitrification operations.

2.1.3.6 Solid Waste Stream Components

After the HLW has been converted into a solid form, the hazards associated with regard to radiological releases and potential radiation doses are significantly less. Likewise, hazards associated with the operation of components which process the solid waste form and potential accidents involving those components are greatly diminished. See Tables C.9.3-2, C.9.3-4, and C.5.2.6-1 of WVNS-SAR-003. The solid waste stream components of the VP include the following: (i) turntable, (ii) weld station, (iii) decontamination station, (iv) canister transfer cart, and (v) HLWIS. Following are discussions of radiological safety aspects associated with each of these solid waste stream components.

Turntable

Description

The turntable is the device that holds the canister during filling with molten glass and retains the canisters filled with solidified glass wasteform until they are cool enough for further processing (to a centerline temperature of approximately 550 °C). Since cooling from the approximate 1,150 °C pour temperature is a lengthy process, two stations in the turntable are allowed for canister cooling after pouring. One station is available for moving a cooled full canister out of the turntable and replacing it with an empty canister. The turntable rotates to move the next unfilled canister into position for filling. The turntable precisely locates the canister beneath one of the two pour spouts of the melter as it is being filled. Three independent means are available to determine proper alignment: (i) shield window viewing of alignment marks, (ii) closed-circuit TV viewing of alignment marks, and (iii) load cell platform centering. The station at which the canister is positioned as it is being filled is located under the pour spout of the melter. An electronic interlock prevents turntable rotation when there is air flow to the molten glass airlift so the canister does not move while pouring is in progress. Ventilation from the off-gas system is used to remove potential contaminants from the air between the pour spout and the canister.

Three techniques are available to determine when the 80 percent canister fill goal has been reached during pouring: (i) a load cell, (ii) an infrared level detection system (ILDS), and (iii) mass balance calculations. Two of these three must be in agreement for airlift operations and pouring from the melter to continue. Overfilling of canisters is not a significant concern, since greater than 8 hr are required to fill from 80 percent to 100 percent. After filling, canisters are removed either to the canister weld station or to temporary storage at the canister storage rack.

Canisters are placed into and removed from the turntable with the remotely operated cell crane and canister grapple. In case of malfunction, the turntable drive components are remotely replaceable with the cell crane.

Margin of Safety

In-cell components, including the turntable, have been reviewed for structural and anchorage integrity. The in-cell, off-gas framework was analyzed against seismic loading for yielding of the stationary frame, pounding against the melter support frame, and failure of the turntable support. No failure was predicted from analysis for seismic events with margins of safety greater than 2.3 × DBE. This value, given in the February 1995 meeting (Rowland, 1995), is slightly greater than the 2.1 margin given in Table C.5.2.6-2 of WVNS-SAR-003. No credible failure scenario exists for the turntable with respect to tornado loading.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

The turntable is designed for remote maintenance and replacement. Hazards associated with the turntable are relatively small. Three independent means are available to determine proper canister location before melt pour. Multiple technologies and associated components are used to prevent overfilling of canisters, which is the most likely accident associated with the turntable.

> *Evaluation: This design complies with the concept of cascading pressures for control of the flow of contaminated air by controlling airborne contaminants during the pour process by using the low pressure in the off-gas system to direct contamination toward filtration. In addition, multiple barriers of confinement exist since the turntable lies within another confinement barrier, the SS-lined floor of the VC. Defense-in-depth is incorporated in the design by two means. Multiple technologies are used to prevent overfilling canisters and any associated spills, and three independent means are available to indicate the level to which the canister has been filled. The length of time required to fill from 80 percent to 100 percent (greater than 8 hr) mitigates the potential for overfilling. The structural design analysis is in conformance with accepted engineering standards. The lowest modes of the system are 6.1 and 7.7 Hz, within the amplified region of the response spectrum. Therefore, the dynamic analysis performed is appropriate.*

Canister Weld Station

Description

After transportation by the cell crane to the canister weld station, a small sample of the glass shards at the top of the canister is removed. One out of every ten of the canisters will be tested for glass quality at this time, and samples from all canisters will be archived. Filled canisters are fitted with lids, that are remotely welded. The weld process is visually observed with remote cameras and directly observed through the shield windows, and weld process parameters are monitored to confirm weld quality. If a bad weld is detected, three weld repair procedures are available, including one in which a second lid is installed over the first.

The solid waste form within the canisters at the time of handling at the weld station limits potential radiological hazards. The greatest hazard at the weld station exists during handling of the canister—during transportation to and from the Weld Station with the cell crane. The canisters are designed not to fail as a result of a 7-m drop on an unyielding surface. Accident analyses presented in Section 9.4.6 of the WVNS-SAR-003 indicate that the airborne fraction from a canister drop, before or

after filling, would result in extremely small on-site or off-site doses. If HVAC filtration is not available during such an accident, resultant total effective dose equivalents (TEDEs) are still well within EGs.

Canisters are handled by the cell crane with a grapple attachment that lifts the canister by its upper flange. Canisters are stored in an eight-place Canister Storage Rack after welding, with the option of also storing canisters there before welding. If uncapped canisters are stored in the storage rack, they are fitted with a temporary lid to keep extraneous material from entering the canister.

All in-cell canister weld equipment can be repaired remotely, and exposure of electrical and electronic equipment to radiation has been limited to prevent damage and to facilitate maintenance.

The weld station is anchored to the VF reinforced concrete floor with epoxy anchor bolts whose margin against seismic failure is greater than 4×DBE. Resistance to the 95 °F ambient operating temperature and radiation field near the welder was discussed and resolved during the February 1995 meeting at West Valley (Rowland, 1995).

Margin of Safety

The canister weld station has been designed for structural integrity and anchorage under UBC Seismic Zone 3 forces with an importance factor of 1.5. The margin of safety was estimated to be greater than 1.8×DBE in Table C.5.2.6-2 of WVNS-SAR-003, using engineering judgment, although more recent information indicates that this margin of safety is based on a re-evaluation performed by Dames & Moore (Rowland, 1995). Equipment other than passive confinement needs only to satisfy a margin of safety greater than 1.0×DBE.

For the in-cell canister storage rack, the lowest margin of safety from Table C.5.2.6-2 is 1.5 for buckling of a main transverse brace of the frame. The margin for support failure and pounding against the turntable is greater than 3×DBE.

No credible failure scenario exists for the weld station or canister storage rack with respect to tornado loading.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

This design incorporates multiple barriers of confinement. The weld station lies within another confinement barrier, the SS-lined floor of the VC. Airborne contamination from a canister drop is confined by the HVAC system. Two methods are available for monitoring weld quality, and multiple repair procedures are available if a bad weld is detected.

> *Evaluation: Seismic integrity for both the weld station and the canister storage rack appear to be acceptable for the potential hazards that exist there. Independent dynamic analysis for these systems was performed by Dames & Moore and resulted in lowest modes within the amplified region of the response spectra. Therefore, dynamic analysis is appropriate. The Dames & Moore reference (1994d) indicates that no independent review of the weld station was performed, although the information provided by Dames & Moore in the February 1995 meeting (Rowland, 1995) indicates differently. For monitoring weld integrity, no mention is made in the WVNS-SAR-003 of consideration of the use of other available technologies such as ultrasonic testing*

and x-ray examination for quality control of weldments. Future revisions of the WVNS-SAR-003 would benefit by offering a rationale for not adopting such technology. Multiple available weld procedures provide defense-in-depth for the weld process.

Canister Decontamination Station

Description

The canister decontamination station is designed to remove external contamination from the canister after welding. Such contamination is anticipated to be difficult to remove (described in WVNS-SAR-003 as "baked on"). Decontamination is accomplished by a "chemical milling" process, whereby powerful acids etch a small depth of surface (0.0002 in.) from the canister. The decontamination solution consists of 5 percent dilute nitric acid and ceric (Ce^{+4}) nitrate. The process is limited in depth of surface removal by available quantity of ceric ion (Ce^{+4}), the reactant, and control of temperature and time in the decontamination solution.

The canister is positioned within the decontamination tank, the bolted tank lid is secured, and the decontamination solution is gravity-fed into the tank. During the 6-h residence time within the heated (65 °C) tank, sparger air agitates the solution. After the decontamination period, the solution is reduced with hydrogen peroxide to reduce the Ce^{+4} to Ce^{+3} and make it nonreactive. The decontamination solution is transferred to a neutralization tank, from which it is transferred, in turn, to the SBS and to the CFMT. A second, flushing batch of dilute nitric acid is used during normal operations to decontaminate the canister. For every 65 hr of operation (the approximate time allowed for filling a single canister), two nitric acid batches are expected to be prepared.

The CCS provides decontamination and flushing solutions that are used during decontamination of canisters. Such solutions include demineralized water, dilute nitric acid, dilute sodium hydroxide, mild detergent solution, dilute oxalic acid, dilute potassium permanganate, and dilute potassium dichromate. Pumps and lines are flushed between transfers to prevent unwanted chemical mixing or residence times which could be detrimental to equipment life.

If smear samples remotely taken from the canister after decontamination indicate it is necessary, the canister can be decontaminated a second time. After decontamination is complete, canisters can be either transferred to the canister storage rack or to the transfer cart for transport to the HLWIS.

Margin of Safety

The canister decontamination station has been designed for structural integrity and anchorage under UBC Seismic Zone 3 forces with an importance factor of 1.5. The margin of safety was estimated to be greater than 1.9×DBE in Table C.5.2.6-2 of WVNS-SAR-003, using engineering judgment.

No credible failure scenario exists for the canister decontamination station with respect to tornado loading.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

This design incorporates multiple barriers of confinement. The Decontamination Station lies within another confinement barrier—the SS-lined floor of the VC.

Evaluation: Seismic integrity for the decontamination station appears to be acceptable for the potential hazards that exist there. This is based on the conservatism inherent in the UBC requirement and the independent assessment performed by Dames & Moore. WVNS-SAR-003 does not adequately discuss the effects on the quality of melter feed for vitrification of recycling the decontamination solution after neutralization. Future revisions of the WVNS-SAR-003 would benefit by adding such information.

Canister Transfer Cart

Description

Canisters are transferred through the transfer tunnel and EDR to the HLWIS by the canister transfer cart. The cart can transport four canisters at a time. It receives canisters from either the weld station or the storage rack, as canisters are handled with the grapple and cell crane. The motorized cart travels on rails from the VC, through the EDR, and into the HLWIS. The cart is radio-controlled and powered by batteries, with four completely independent drive trains. The PHA is given in Table C.9.3-3.

Margin of Safety

The canister transfer cart has a margin of safety against seismic loading greater than 1.8×DBE. This value appears in Table C.5.2.6-2 of WVNS-SAR-003 where engineering judgment is listed as the basis of assessment. A mitigating factor is the limited time (0.4 percent of the vitrification campaign) during which the canister transfer cart is in operation. In the information on the fundamental frequency provided by Dames & Moore at the February 1995 meeting (Rowland, 1995), the margin of safety is given as greater than 1.0×DBE.

No credible failure scenario exists for the canister transfer cart with respect to tornado loading.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

This design incorporates multiple barriers of confinement since all cart transfers occur within areas served by HVAC systems.

Evaluation: Seismic integrity for the canister transfer cart appears to be acceptable for the potential hazards that exist there. The design and analysis are in accordance with standard engineering practice. Also, the reduced time during which canisters are moved with the cart reduces the probability of occurrence below that for the seismic DBE.

High-Level Waste Interim Storage

Description

The HLWIS facility is designed to store the solidified HLW in 270 to 300 decontaminated canisters until they can be shipped to a federal repository. The cell floor and walls of the HLWIS are lined with SS up to a height of 0.46 m, and interior concrete surfaces are coated with a radiation-resistant paint. HLWIS dimensions are 28.3 m long, 6.7 m wide, and 13 m high. Reinforced concrete walls are 1.8 m thick. During vitrification, primary access to the HLWIS is through a tunnel to the EDR. The tunnel is shielded with a concrete-filled shield door, 3.4 m wide, 1.2 m thick, and 4.3 m high, which moves horizontally.

Operations within the HLWIS are aided by the ability to view directly through four shielded windows that use lead glass filled with mineral oil. Closed-circuit TV cameras are also used.

The HLWIS facility is an existing structure that was referred to as the CPC during its prior use for spent-fuel recycling. The crane serving the HLWIS is referred to as the CPC crane, and it can be isolated from the HLWIS for maintenance in the CPC crane room. The CPC crane room can be accessed through a vertical lift 0.9-m-thick shield door.

The HLWIS facility is protected against airborne contamination by HVAC ventilation (main plant/head end ventilation system) which is reviewed in Section 2.1.3.8 of this SER.

The HLWIS facility is also designed to store failed equipment after removal from the VC. Glass shards removed from canisters for archiving samples are also stored in the HLWIS.

Two accidents were considered for the HLWIS in WVNS-SAR-003: Failure of the HLWIS roof and crane fall, neither of which can occur at DBE levels of seismic activity. Both on-site and off-site doses resulting from these incredible events remain within EGs.

Margin of Safety

No credible failure scenario exists for the weld station or canister storage rack with respect to tornado loading.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

The HVAC filtration prevents contamination from exiting the HLWIS. The solid waste form within the HLWIS minimizes potential releases during accidents. The HLWIS structure incorporates another confinement barrier, the SS-lined floor.

> *Evaluation: Structural analysis for the HLWIS was not performed as part of the margin study for the WVNS-SAR-003. However, analyses performed by both the Los Alamos National Laboratory (LANL) and LLNL indicate that lateral piles for the building foundation can withstand seismic loads in excess of 1×DBE. The consequence of failure of the storage facility will not produce any significant release, since the HLW stored in the HLWIS is already in a solid form.*

2.1.3.7 Gaseous Waste Stream—Process Off-Gas System

Description

The process off-gas system is one of three distinct ventilation systems that provide active confinement. The other two confinement ventilation systems are discussed later in this SER. They are (i) the VB HVAC system, that also services the VC; and the (ii) HLWIS and EDR Ventilation, that utilizes the existing main plant and head end ventilation systems.

The process off-gas system at WVDP provides control of contamination and removal of radioactive particulates to reduce their concentration within acceptable limits before release to the atmosphere. The off-gas system is used to maintain a slight vacuum on the melter and process vessels so that off-gases will be directed through equipment which removes radioactive particulates. This prevents off-gas from entering the surrounding air such as the ambient air in the VC, and it concurrently prevents the contamination that such releases may cause.

Although the off-gas systems are described in various places in the WVNS-SAR-003, a brief description is provided here for clarity. For further detail, refer to the WVNS-SAR-003, particularly Sections C.4.5.3.2, C.5.2.6.10, C.5.2.7.4, C.5.5.4, C.6.2.3, C.6.3, C.7.4.1, C.9.4.3, C.9.4.7.1, and C.9.4.9.

The process off-gas system controls and conditions melter off-gas and process vessel off-gas in a system whereby the two flows are combined [see Figure 2-6 (taken from Figure 6.3.1-2 of WVNS-SAR-003)]. Table 6.3.1-1 of the WVNS-SAR-003 summarizes off-gas system design data and is reproduced as Table 2-5. The off-gas from the melter passes through the film cooler, the SBS, and a mist eliminator before being combined with the noncondensible off-gases from the CFMT and the MFHT. The film cooler incorporates an automated, replaceable corrosion-resistant brush to periodically remove any solids that may accumulate in the off-gas at the melter. The film cooler and the SBS cool the SFCM off-gas from 300–400 °C to 60 °C. The SBS is a passive device that bubbles off-gas through water in a bed of ceramic spheres. Excess liquid from the SBS is recycled back to the CFMT. The combined flow is then conditioned both within the VC and subsequently in the 01-14 Building before being released through the 60-m main plant stack. Within the VC, the combined flow passes through a HEME preheater (to avoid condensate forming on the HEPA filters), and two HEPA filters in series. Each of these components is provided with redundancy for backup. The in-cell HEPA filters are referred to as prefilters since they cannot be DOP tested in place. The off-gas exiting the prefilters is reheated in a post-heater and transferred to the 01-14 Building in an insulated duct in the off-gas trench.

The flow from the vessel vent header system will be heavily laden with evaporated moisture, and this water is removed by the vent header condenser before subsequent joining with the flow from the SFCM off-gas. The condensate from the vessel vent header condenser is returned to Tank 8D-3 for subsequent processing. The vessel vent header can also accept redirected flow from the SFCM off-gas in case vacuum is lost there.

Those components of the off-gas system located outside the VC are called the ex-cell off-gas system [see Figure 2-7 (from Figure C.5.5.4-1)]. After leaving the VC, the combined off-gas flow passes through a 10-in., Schedule 10, 304L SS pipe, supported in a shielded, reinforced concrete trench. The ventilated trench is coated with epoxy and drains by gravity to the entrainment separator. In the 01-14 Building, off-gases enter the entrainment separator to remove condensation that may result as the off-gas

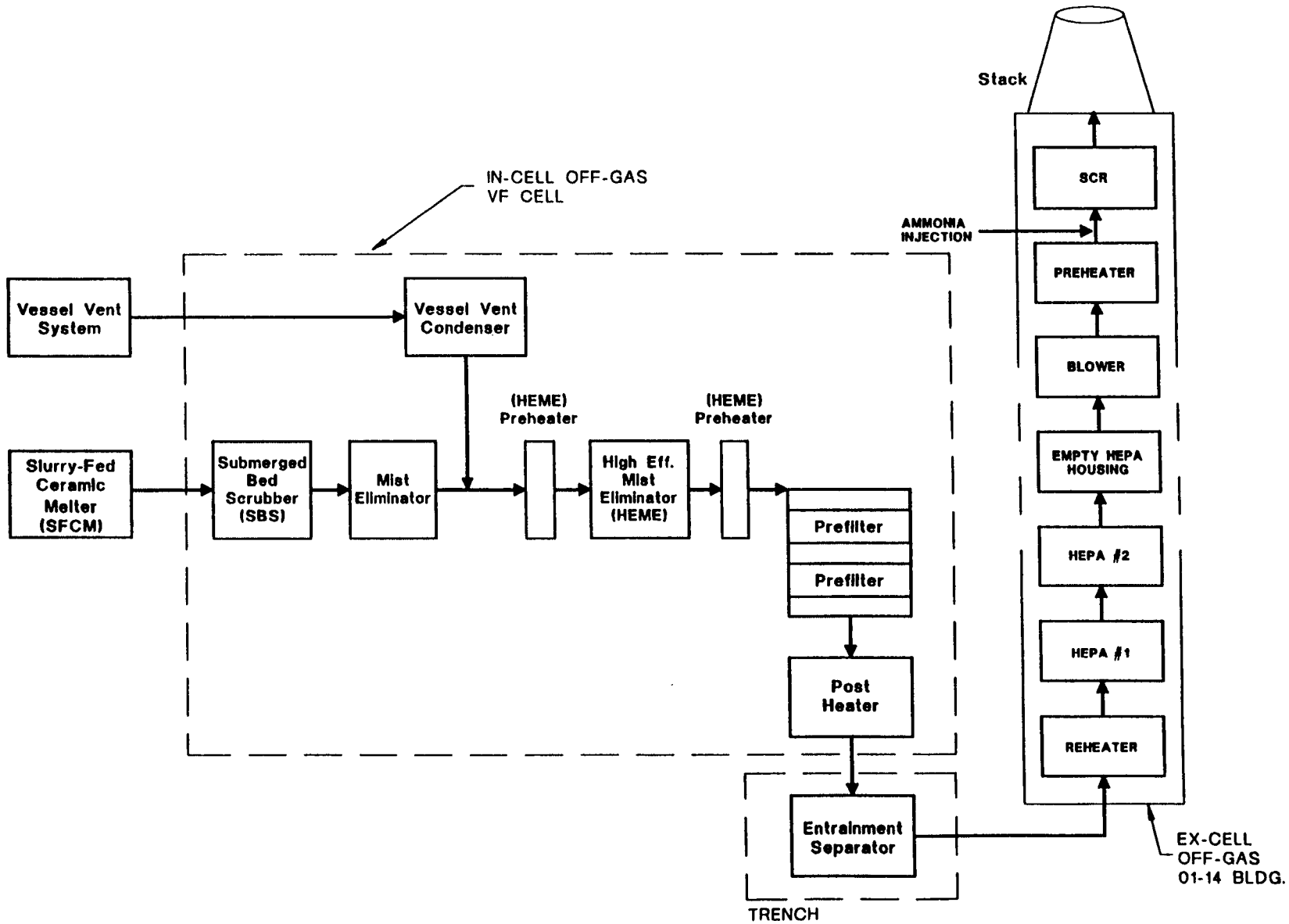


Figure 2-6. Process off-gas system flow (WVNS-SAR-003, Rev. 2, Draft D, Fig. C.6.3.2-2)

Table 2-5. Off-gas system design data (WVNS-SAR-003, Rev. 2, Draft D, Table C.6.3.1-1)

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 (3×10^6 BTU/hr) vertical shell and U-tube heat exchanger, 760 mm diam. by 3,350 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 3,30 mm tall, 5.5 m^3 working volume. Inside the receiver vessel is a Hastelloy C-22 scrubber vessel with 2.27 mm^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; 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; 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

Table 2-5. Off-gas system design data (WVNS-SAR-003, Rev. 2, Draft D, Table C.6.3.1-1) (cont'd)

Item	Component	Description
12	Reheater	304L SS housing; 60 kW, 480 volt, 3 phase, electrical resistance immersion style elements 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 with set point for 37 and 42.5 m^3/min (1300 & 1500 ACFM); 75 hp, 460 volt, 3 phase
15	Preheaters	Insulated 304L SS housings holding two 101 kW, 480 volt, 3 phase, electrical resistance immersion style element sheathed in Incoloy 800
16	NO_x Destruction Reactors	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; 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

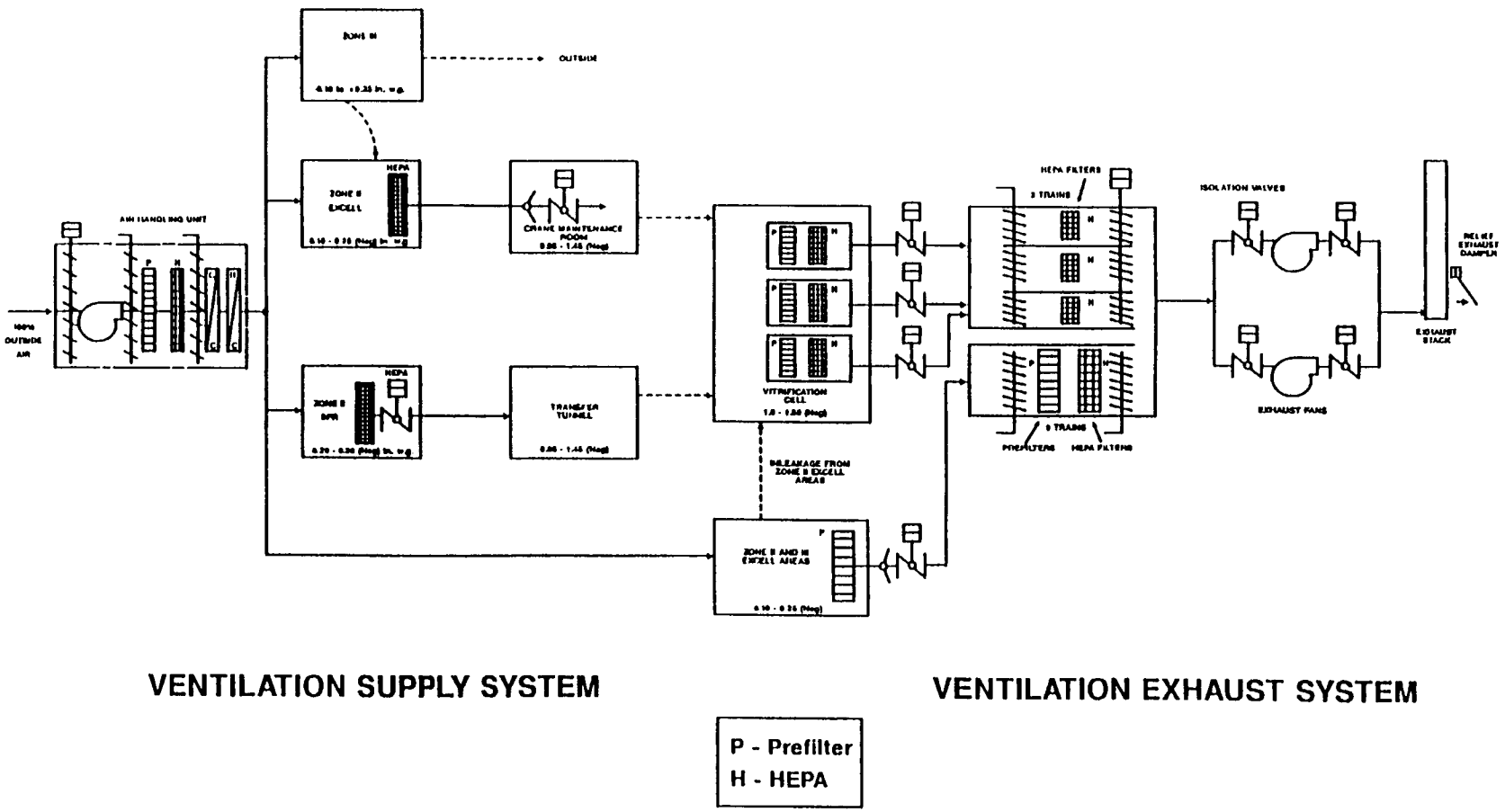


Figure 2-7. Ex-cell off-gas system components (WVNS-SAR-003, Rev. 2, Draft D, Fig. C.5.4.1.1-3)

is cooled in transfer. The entrainment separator is located in the lowest elevation of the off-gas line so that it can drain the entire off-gas duct. Condensed liquid drains to the south sump of the VC, where it is cycled back into Tank 8D-4 by the waste header system. Next, the off-gas is reheated before entering more HEPA filters and the blower and exiting from the stack. An ammonia system is used to treat the off-gases before leaving the stack for abatement removal of oxides of Nitrogen (NOX). All off-gas equipment in the 01-14 Building is designed for manual maintenance since the prefilter assembly within the VC is expected to prevent significant contamination from reaching the ex-cell off-gas equipment. The HEPA filters are monitored routinely so they can be changed out if the radiation field rises to a significant dose level. Also, the pressure differential across each HEPA filter is continuously monitored, and the installed backup HEPA filter train would be automatically valved into service if the differential pressure exceeds a preset value.

The NOX abatement catalyst bed is expected to collect a small quantity of radionuclides, so that the dose at 2 ft should be less than 7 mrem/hr after 1 yr of operation (Vance, 1989).

The ammonia system within the 01-14 Building was reviewed for its potential fire hazard since any fire in Building 01-14 could put the off-gas equipment there at risk. Anhydrous ammonia is stored in a 1,000-gal. tank north of the 01-14 Building. It is used in the selective catalytic reduction (SCR) technique to reduce nitrogen oxide emissions. The tank is instrumented and fitted with redundant pressure relief valves, a solenoid-operated shutoff valve, and excess flow check valves, and it is protected with a water-based suppression system for fire protection, vapor reduction, and reduction of concentration. Anhydrous ammonia is DOT-classified as a "non-flammable gas" per NFPA 49, and NFPA 325 M lists an ignition temperature of 1,204 °F, with lower and upper flammability limits of 15 and 28, respectively (West Valley Nuclear Services Company, Inc., 1994c). The conditions for an anhydrous ammonia fire require several simultaneous unfavorable circumstances, so that a single contributing factor would not be sufficient to cause an anhydrous ammonia fire.

A significant leak of anhydrous ammonia that could cause a health hazard to operating personnel with important administrative duties has a higher annual probability (5.2×10^{-3} for loading accidents) than an anhydrous ammonia fire (10^{-4} to 10^{-6}), per Table C.9.3-6 of WVNS-SAR-003. Potential causes for a significant leak include human error during tank filling, impact by a vehicle, impact by tornado missiles, impact by components of the 01-14 Building during a seismic event, or impact by items being suspended by an overhead crane. Protection of operating personnel is provided by a water-based suppression system for vapor reduction and reduction of concentration. As noted previously, operation of off-gas process equipment within the 01-14 Building is not crucial to radiation safety since the prefilter assembly within the VC is expected to prevent significant contamination from reaching the ex-cell off-gas equipment.

Downstream of the SCR unit, ammonium nitrate (NH_4NO_3), a potential fire and explosion hazard, is generated in very small quantities (2g/yr of operations). The potential for generation and accumulation of NH_4NO_3 in the off-gas system was evaluated along with the physical and chemical conditions that must exist for the compound to be hazardous (Goles, 1990). No credible mechanism for accumulating exhaust system combustibles downstream of the SCR could be identified. The necessary confinement conditions for deflagration and/or explosive hazards cannot be established by the very limited quantities of NH_4NO_3 involved. Temperature conditions required to support spontaneous combustion of the NH_4NO_3 cannot be obtained at the stack, which is the only likely location where a combustible inventory could develop.

For normal operations, the confinement system represented by the off-gas processing system within the VF is required to function to maintain cumulative operating releases and doses below pertinent limits. Off-gas releases are discussed in Section 2.3 of this SER. Accident conditions are discussed in Section 2.4 of this report, where it is noted that no active role is required of the off-gas processing system to maintain on-site and off-site doses within EGs.

Margin of Safety

In-cell support framework and interconnected process components have been reviewed for structural and anchor integrity. The in-cell off-gas framework was designed for structural integrity and anchorage under UBC seismic Zone 3 force with an importance factor of 1.5. The margin of safety for in-cell process off-gas equipment is listed in Table C.5.2.6-2 as greater than 1.7×DBE for both yielding of the frame and support failure.

Ex-cell off-gas equipment includes the off-gas trench and the equipment in the 01-14 Building. Ex-cell off-gas equipment is not seismically qualified; it is not required to maintain on-site and off-site doses within EGs. Since the 01-14 Building was not designed to withstand tornado loads, the off-gas equipment there would not be expected to survive the DBT. The in-cell filters are expected to collect the significant proportion of off-gas radioactive contaminants [decontamination factor (DF) $=10^5$], with the result that releases from the ex-cell off-gas equipment, due to a DBT, would not exceed acceptable limits.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

The in-cell process off-gas equipment is designed with parallel and redundant HEME units and HEPA filter exhaust trains. Those components that are not installed in a redundant arrangement can be replaced remotely, and spares for each are available. In-cell filters are designed to withstand the DBE. HEPA filters are monitored for radiation and differential pressure to indicate when they need replacement. The in-cell process off-gas equipment is protected by another barrier to release, that barrier being the VC reinforced concrete boundary and its special doors and viewing windows.

The ex-cell off-gas system is designed with redundant equipment trains so that a spare system is available when maintenance is required or in case of equipment failure. Redundancy is provided for the reheater and HEPA filter trains. The blowers that draw air through the entire off-gas system are provided with double redundancy so that there are two backup units. Thus, during maintenance, a backup blower is still available. The pressure relief valves on the blower discharges relieve to the suction side of the blowers, so that pressure is not relieved to atmosphere and confinement is maintained.

Ex-cell off-gas system components are protected by at least one additional confinement barrier (the trench for the off-gas pipe between buildings and the 01-14 HVAC system for equipment within the 01-14 Building).

The NOX abatement system is also provided with redundancy so that cascading pressure control in the off-gas system is maintained.

The ex-cell off-gas system is monitored and partially controlled from the VF CR. Instrumentation is energized with a UPS in case of loss of available electrical power.

Loss of off-site power supply is protected against by a diesel generator unit and UPSs. Active (powered) function of the off-gas system is not required, however, to maintain occupational and public doses well within acceptable limits.

Expected annual release rates and concentrations of radionuclides released from the process off-gas stack are provided in Table C.6.2.3-1 of WVNS-SAR-003, and they are discussed in Sections 2.1.3.7 and 2.2.1 of this SER.

Evaluation: This design complies with the concept of cascading pressures to control the flow of contaminated air (in this case, off-gas) from less contaminated zones to more highly contaminated zones. In addition, multiple barriers of confinement are utilized. All off-gas lines lie within another confinement barrier (e.g, the VC for in-cell release, the off-gas trench between buildings, and the 01-14 Building HVAC). Defense-in-depth is incorporated in the design by (i) redundancy of important components including both in-cell HEPA (pre-)filters and those HEPA filters located in the 01-14 Building farther downstream; and (ii) redundancy of blowers in the 01-14 Building. The potential for development of hazards associated with anhydrous ammonia and with ammonium nitrate has been adequately considered and is not significant.

The design and analysis of the process off-gas structure is in accordance with standard engineering practice. Use of a dynamic analysis for the seismic event is acceptable based on the calculated modes of the system that lie in the elevated portion of the required response spectra.

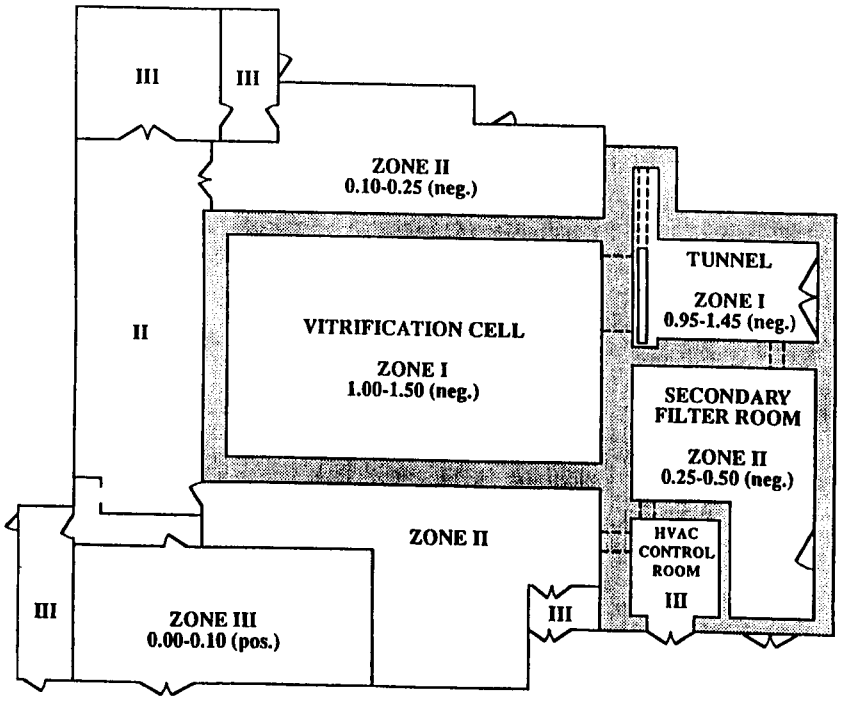
2.1.3.8 Gaseous Waste Stream—Heating, Ventilation, and Air Conditioning System

Although the HVAC systems are described in various places in the WVNS-SAR-003, a brief description is provided here for to clarify and to identify pertinent design features. For further details, refer to the WVNS-SAR-003, particularly in Sections C.4.5.2.5, C.4.5.3.3, C.5.4.1 and its subsections, C.5.5.2, C.5.5.3 and its subsections, C.6.3, C.6.3.2, C.7.4.2, C.8.3.3, C.9.4.4, C.9.4.5, C.9.4.7.2, C.9.4.8, C.9.4.9, C.9.4.10, C.9.6.2.1, C.9.6.2.2, and C.9.6.3.

Description

The three primary functions of the HVAC systems are: (i) to direct airflow to aid in confinement, (ii) to control the operating environment of equipment and components, and (iii) to control environmental conditions for operating personnel. The direction of airflow is controlled so that ventilation flows from areas with lower potential for radiological contamination to areas with higher potential for radiological contamination. This is achieved by control of ambient air pressure between multiple zones within the facility. This concept of cascading pressures is made effective by controlling dampers and other flow restrictors between each of three ventilation zones.

For the VF HVAC, the three ventilation zones are illustrated in Figure 2-8, taken from Figures 5.4.1.1-1 and 5.4.1.1-2 of the WVNS-SAR-003. Zone I areas are designated as those that contain the highest level ("a significant amount") of airborne contamination during normal operations. Zone I includes the VC, which contains the melter and batch tanks for glass-forming slurry containing HLW. Zone II is immediately adjacent to Zone I, and it provides a buffer to Zone I releases. Zone II could



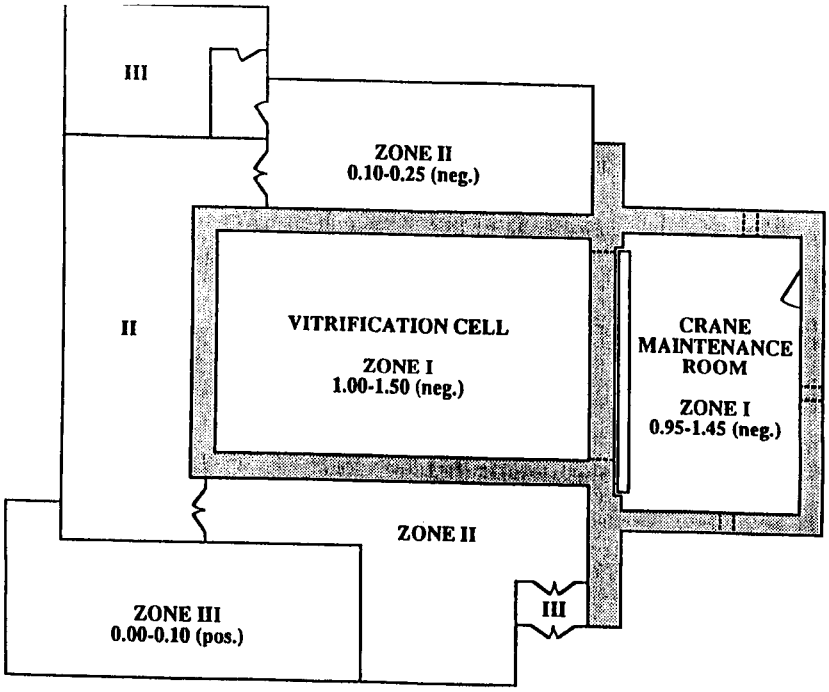


Figure 2-8. Ventilation zones of the vitrification facility (WVNS-SAR-003, Rev. 2, Draft D, Fig. C.5.4.1.1-1)

contain airborne activity, but airborne activity in Zone II is anticipated to occur only very infrequently. Zone III areas are expected to remain free of any contamination. Zone III includes those areas that are planned to be continuously manned, such as the main CR. Infiltration air for ventilation flows from outside into Zone III, to Zone II, and finally to Zone I, before being evacuated through banks of multiple HEPA filters for control of radiological releases through a stack. The use of such controlled zones in directing the flow of any airborne contamination is common practice when handling radioactive materials.

Control of infiltration air also depends on the integrity of zone boundaries, the most important of which is that for Zone I. Confinement structures supporting the HVAC design are discussed in Section 2.1.3.3 of this SER, including special doors, windows, the VC, and infiltration.

Significant HVAC design features include the use of redundancy and diversity in components for reliability control; limiting flow to 30,000 cfm; instrumented control to control infiltration and exhaust flows; accessibility of filters for change-out; accessibility of components for change-out; ability to isolate fans and filters for maintenance; test sections provided for HEPA filter testing with DOP; and component design and testing conforming to ANSI/ASME N509 (American Society of Mechanical Engineers, 1976) and ANSI/ASME N510 (American Society of Mechanical Engineers, 1975), respectively. Primary HEPA filters are located as near as possible to contamination sources to limit spread of contamination. Three HEPA flowpaths are available so that redundancy for the in-cell filtration is assured at all times, including maintenance to change-out filters. Each flowpath includes a prefilter and a HEPA filter. The prefilter is identical to the HEPA filter but, since it cannot be DOP-tested if it is replaced, it is not referred to as a HEPA filter. It is, however, DOP-tested prior to initial installation.

The VB HVAC system is designed to maintain confinement of Zone I during and after a DBA or event. Infiltration air entering Zone III of the VB is HEPA filtered as it is conditioned for temperature, except at entry doorways. HEPA filters are also located between Zone I and Zone II to filter inadvertent backflows from Zone I during upset conditions. Stairways are pressurized and ventilated in accordance with NFPA requirements for safe passage of personnel. Particulate loading of exhaust filters is reduced (and frequency of change-out period is extended) by the use of prefilters.

Dual systems are in place for monitoring and controlling VC ambient air pressure; this is important in maintaining the cascading pressures between zones. If the VC negative pressure cannot be maintained by the system, an automatic system isolates the VC and shuts off the supply fan. During normal operations, VC vacuum is maintained by an automatic system that has the ability to control exhaust air flow, pressurize stairways, operate vacuum relief dampers, and open dampers to provide outside cooling air to the SFR and Crane Operating Aisle. Smoke detection equipment can also automatically isolate supply and exhaust fans to control the spread of fire.

Temperature and humidity control for maintenance of equipment operating conditions and human comfort is provided by chilled water and refrigerant systems (for cooling) and steam and electrical heating systems (for heating). The VC temperature is cooled to near 100 °F by removing process heat (from the melter and evaporation of excess slurry water) through in-cell coolers. The in-cell coolers are suspended from the VC roof, and they are designed to induce filtered VC air through a heat exchanger employing chilled water. Exhaust air from the in-cell cooler is directed toward the sources of process heat. Operating aisles and the CR are maintained at temperatures suitable for occupancy of shift operating personnel by circulating air through one of two heat exchangers (one spare) employing chilled water and

refrigerant for cooling and electrical heaters for heating. Supply air to the CR is HEPA filtered to prevent contamination from airborne radioactive particles. CR air is automatically isolated via redundant smoke detectors.

Air exiting the VC is exhausted from the three in-cell filters via three dedicated ducts, each of which may be valved off for isolation. Exhausted air passes through flexible connectors at the secondary filter unit.

The flexible connectors serve to seismically isolate the secondary filter equipment from vibration such as that associated with seismic events. The flexible connectors are made of polychloroprene, which has a kindling temperature of 1,652 °F and which will not support combustion without a sustained heat source. Three potential sources for combustion for the flexible connectors were considered in the review of WVNS-SAR-003: (i) molten glass (temperature to 1,225 °C, or 2,235 °F), (ii) combustion of process ammonia, and (iii) acetylene combustion potentially available during maintenance. Molten glass does not have an available path to ignite the connector. Process ammonia is used in the 01-14 Building, which is separate from the VB, and there is no available path for a sustained ammonia fire to reach the connector (West Valley Nuclear Services Co., Inc., 1994c). Unplanned maintenance in which acetylene might play a role would be under administrative control, via WVNS Welding Codes and Procedures and the Industrial Work Permit (Westinghouse Risk Assessment Services, 1994). Inadvertent surface combustion of the connector that might occur in spite of such control would only be possible if the flame were directed at the connector. WVDP personnel would obviously avoid this, but, if it were to occur, such an incident would be immediately evident to maintenance personnel. Minor surface deterioration that might result would be insignificant with respect to the function of the flexible connector.

In the secondary filter unit, three parallel trains, each containing three HEPA filters, are available for further filtration of air exhausted from the VC and the in-cell filters. Like the in-cell filters, a redundant filter is available at all times, even when one filter is being changed out during maintenance. The exhaust plenum of the secondary filter unit is shared with exhaust from dual HEPA filters that process the prefiltered exhaust air from Zone II and III ex-cell areas. Air is drawn through the exhaust plenum by two parallel exhaust fans, each of which can be isolated for maintenance or replacement. Since two fans are available, no redundant fan would be available if one fan were inoperable due to maintenance or replacement. The HVAC stack, which is separate from the off-gas processing system stack, is fitted with a relief exhaust damper so that HVAC exhaust can continue if the stack becomes unserviceable.

The release point from HVAC exhaust is located to minimize the possibility of drawing in contaminated air via the HVAC infiltration air.

For protection against tornadoes, tornado dampers are provided to prevent backflow during the short-term, low-pressure tornado event (Kupp, 1989). The dampers require no external power source to operate, and they are located at the CMR intake, the HVAC CR supply, and the SFR supply. For protection against tornado missiles, tornado missile barriers are installed to protect the exhaust duct where it exits the VB up to the pressure relief valve, from which point the duct is considered expendable in a tornado event. The pressure relief valve, which bypasses the stack in case of tornado damage, is also protected with a tornado missile grating. Other HVAC ducts and accessories are protected against tornadoes and tornado missiles by the passive confinement barrier provided by the reinforced-concrete vault, special doors, and shielded viewing windows.

The chiller equipment room is ventilated by a dedicated axial fan, that is thermostatically controlled and supplied by air from outside the building through a fail-open damper. The chiller equipment room is not supplied with ventilation from the ex-cell ventilation system.

Standby power is available to the valves isolating the VC, to fan controls, and to stair fans.

Three distinct ventilation systems provide active confinement: (i) the VB HVAC system, which also services the VC; (ii) HLWIS and EDR Ventilation, which utilizes the existing main plant and head end ventilation systems; and (iii) the process off-gas system, which is discussed in Section 2.1.3.7. In addition to the VB HVAC (which includes in-cell coolers VF CR HVAC, and DGR HVAC), WVNS-SAR-003 includes discussions on CCB HVAC, 01-14 Building HVAC, and main plant HVAC HEV (which serves the HLWIS). Discussions on design basis and description for each of the other HVAC systems (other than the VB HVAC) are given in other DOE-approved safety documentation.

The EDR, which is part of the VB, normally receives ventilation air from the "truck lock," with which it interfaces. Exhaust air from the EDR is transferred to the CPC, which is kept at negative air pressure by the HEV system. The transfer tunnel, which also interfaces with the EDR, is ventilated by the Vitrification HVAC system. Air transfer between the two systems can occur when the transfer tunnel is being used to transfer equipment between the VC and the EDR. Air transfer is minimized by maintaining the Transfer Tunnel and the EDR at the same pressure under normal operation. A further step to minimizing infiltration to the EDR from the transfer tunnel can be taken by closing both doors at the ends of the transfer tunnel.

The DGR requires ventilation when the diesel is running for cooling and combustion air, and this ventilation is provided from outside air through louvers, that fail open upon loss of power. When the diesel is not running, HVAC is provided by a supply duct from the VB HVAC and by a local electric heater.

The CCB HVAC is separate from the VB HVAC, and it is not required to process air for radiological safety. The CCB is ventilated in a once-through arrangement, with infiltration air heated in winter with steam. In addition, the CCB scale room is ventilated with a filtered fume hood, and supplied with its own air intake to ensure a supply of fresh air. The CCB exhaust air is adequately separated from the VF and CCB air intakes.

The 01-14 Building HVAC conditions air for the VP off-gas equipment that resides there. It also incorporates the concept of cascading pressures so that ventilation flows from areas of lesser contamination to those of higher contamination. Two stages of HEPA filtration are employed to remove contaminants from either the process off-gas system or the ammonia system before blowers discharge air through the stack (separate from the off-gas stack).

The 01-14 Building HVAC contributes minimally to radiological safety, since (i) the off-gas stream is relatively free of contamination by the time it reaches the 01-14 Building, and (ii) contamination from the off-gas processing equipment is only possible in the event of breach of off-gas processing equipment confinement. The 01-14 Building HVAC is reportedly discussed in other DOE-approved WVDP safety documentation.

Ventilation for Pump Pit 8Q-2 (above Tank 8D-2) and Pump Pit 8Q-5 (diversion pit) is provided by the WTFVS, which is outside the scope of WVNS-SAR-003, and discussed in other DOE-approved

WVDP safety documentation. Ventilation for pump pits is provided by the WTFVS. Pump pits are maintained at below ambient pressure to direct air flow into the pits and toward the WTFVS. The WTFVS has redundant ventilation trains, each of which includes a mist eliminator, a heater, a roughing filter, and two HEPA filters in series, with exhaust through the PVS stack. During maintenance activities in which the pit cover is removed, ventilation is provided by an 8-in. SS line which is ventilated by the PVS. Aspects other than ventilation for pump pits and the Diversion Pit 8Q-5 are discussed in Section 2.1.3.1 of this SER.

In keeping with the "Graded Approach," each of the HVAC systems and their components are assigned safety classes and quality levels that are listed in WVDP-204. With respect to radiological hazards, limitation of Safety Class B to those components that provide primary confinement (e.g., concrete hot cell, transfer tunnel, VF shielded viewing windows, etc.) and VC HVAC (e.g., duct-cell exhaust system, primary HEPA filter bank, etc.) is consistent with the safety classification criteria given in Table 2 of WVNS-204 since they are both confinement barriers that are required to remain functional under site-specific design basis events. The HVAC CR is a new engineered confinement barrier structure relied on during accident scenarios, including natural phenomena-induced accident (design basis event) scenarios.

Margin of Safety

The exhaust system has been designed to maintain structural integrity and remain functional during and after the postulated occurrence of the design basis events in combination with normal operating loads such as temperature and pressure. The HVAC ducts and their supports, primary HVAC HEPA filter units, and secondary HVAC HEPA filter units are protected against wind, tornado, and tornado-generated missiles by reinforced concrete structures, special doors, shielded viewing windows, and tornado missile grating.

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 SFR, HVAC CR, DGR, and the associated controls and equipment of these rooms are designed to withstand extreme natural phenomena events.

Although not needed to keep doses within EGs, primary filters within the VC are expected to maintain integrity and remain functional under loading from design basis events. The VB HVAC system can withstand a relatively large seismic event, as shown in Table C.5.5.3-2 of WVNS-SAR-003. This table shows margins of safety against design basis events for components of the HVAC system. For the in-cell primary HEPA filter, the margin is listed as greater than 3×DBE against structural or functional failure. The other in-cell (secondary) HEPA filter, the ducts, and their supports are listed in the table as having greater than 6×DBE against structural or functional failure. This margin was established by both testing and dynamic analysis. The same margin is listed for the ex-cell primary HEPA filter. For exhaust fans, which draw air through the HEPA filters and exhaust air to the atmosphere, the margin of safety against either structural or functional failure is listed as greater than 4×DBE. For all other components in the table, the margin of safety against seismic loads is the same, greater than 1×DBE. All HVAC components listed in Table C.5.5.3-2 of WVNS-SAR-003 should structurally survive the DBE, and the HVAC filters should remain functional. In-cell coolers, which provide a cooling function in-cell, are designed to remain in place, but not necessarily remain functional, during a DBE.

Analyses show that all major process components in the VC pit have a seismic design capacity sufficient to prevent their ultimate failure or collapse from extreme environmental loading in excess of the DBE. Continued operation of the VC HVAC system during and after a DBE event is expected because the HVAC CR, controls, blowers, filter units, UPS, and associated standby diesel generator are DBE-qualified.

No margins were listed in the table for resistance to tornado loads, although it would appear that such would be appropriate for the pressure relief valve and tornado dampers, as a minimum.

Defense-in-Depth, As-Low-as-is-Reasonably-Achievable

Primary HEPA filters are located as near as possible to contamination sources to limit spread of contamination. Three HEPA flowpaths are available so that redundancy for the in-cell filtration is assured at all times including maintenance to change-out filters. Each flowpath includes a prefilter and a HEPA filter.

Length of runs of ventilation ducting is minimized to reduce lengths of contaminated ductwork, and inaccessible areas that could accumulate radioactive materials are avoided in the design by use of removable inspection covers.

Dual systems are in place for monitoring and controlling VC ambient air pressure; this is important in maintaining the cascading pressures between zones. If the VC negative pressure cannot be maintained by the system, an automatic system isolates the VC and shuts off the supply fan.

Multiple flow paths are available for reliable exhaust air flow, and each flow path incorporates multiple HEPA filters. A backup exhaust fan is available, but during maintenance or replacement of one of the fans no backup would be available. A relief exhaust damper in the stack allows continued operation if the stack becomes unserviceable. HVAC exhaust is located away from points at which ventilation air enters the building.

Valves used to isolate the VC, fan controls, and stair fans are all provided with standby power.

Multiple barriers for main plant confinement are as follows: first barrier, piping and equipment to contain the HLW; second barrier, concrete cells of the building and their SS liners and sumps; and third barrier, both the drain system to remove liquids and the main plant HVAC system to filter effluents, maintain cascading pressure zones, and maintain acceptable environmental conditions in work areas.

Active confinement is provided by the HVAC system by maintaining negative internal pressure relative to outside air pressure and relative to adjacent areas in the VB. A filtered HVAC system draws air through the VC and adjacent areas via a system of cascading pressures, as explained in Section 2.1.2.1 of this SER.

The HVAC system used to maintain proper environmental conditions and negative pressure in the third confinement barrier consists of systems that control liquid or gaseous effluent from the VC. The first confinement barrier for the HLW slurry and molten glass consists of process vessels, piping, or containers in direct contact with the HLW, while the second confinement barrier is the VC that has a SS liner up to the 22-ft level. (For liquids spilled within the VC, a below-grade SS-lined process pit and sumps provide confinement.)

In the event of loss of electrical power, a standby diesel generator is available to power instrumentation, controls, and the exhaust fan. The rated capacity of the diesel generator is about 50 percent greater than the standby loads required. Rated capacities of all UPS units exceed power requirements by more than 40 percent. Valves and dampers which are required to operate in the event of loss of off-site power are supplied with an UPS and pneumatic accumulators sized for multiple operations. If the Vitrification HVAC filtration and exhaust system is still unavailable, valves close to isolate Zones I and II from Zone III and supply air is shut off. These valves can be operated with uninterruptible battery power to solenoid valves and hand switches. If cell pressure builds during isolation, it may be vented manually by opening certain isolation valves.

The VF exhaust stack is monitored for radioactivity and high radiation levels, with annunciation in the VF CR.

Redundancy in design is reflected in the in-cell coolers, for which four are installed and two are required to maintain in-cell temperatures within acceptable limits during maximum heat loads. Two fans, one at the inlet and one at the outlet, are fitted to each cooler, and only one is needed for functionality.

The Chilled Water System (CC) supplies chilled water at full-flow during operations, and the CC heat is rejected through heat exchangers to three refrigerant chillers (one air-cooled, two water-cooled). The CC system also supplies chilled water for air cooling in the CR (two air handling units) and elsewhere ex-cell (one air handling unit). The potential for contaminating the CC system through a possible break in the lines feeding the in-cell coolers is limited by the following: (i) CC pressure is greater than VC air pressure, so VC air would not enter the CC system; (ii) VC air would contain minimal particulate contaminants under all conditions during which the melter and process vessels (heat source) remain in operation; and (iii) if one or more in-cell coolers must be replaced, the melter and process vessels need not remain operational, and no driving force exists to draw contamination into the CC system.

Evaluation: The population of structures, systems, and components considered in the WVNS-SAR-003 for the vitrification HVAC system includes all those important to active and passive confinement. The scenarios considered in analysis of margins of safety for the structures, systems, and components of the HVAC are appropriate and complete. The margins of safety for the structures, systems, and components of the vitrification HVAC system indicate that none should fail under design basis loads. For those HVAC system components most important to confinement (primary and secondary filters, ducts and duct supports, fans, and control), margins of safety range from 2.1×DBE to 10×DBE, providing confidence they will survive the DBE. The margins were developed using both standard engineering practice in design and analysis as well as seismic qualification testing.

For the two parallel HVAC exhaust fans, no redundant fan would be available if one fan were inoperable due to maintenance or replacement. These fans are assigned safety class B.

Other Systems

There are many systems at the site that provide support to the effective operations of the VP. The important safety-related systems have been discussed in sections 2.1.3.1 through 2.1.3.8. The others, not described here specifically, were deemed to be non-radiological and non-safety-related, although they may have a secondary or tertiary impact on radiological safety.

2.1.4 Administrative Features

2.1.4.1 General Controls

The VP at the WVDP is a batch operation, where a limited quantity of waste from Tank 8D-2 is processed at any given time. This results in maintaining a low inventory within the processing systems and assists in minimizing the radiological source term during any natural or man-made hazard conditions. As described earlier, the design philosophy for the VF is one that emphasizes the confinement of potential radiological releases. Toward this approach, the primary component that facilitates confinement is the in-cell structure of the VF. Significant credit is taken by the WVDP for the capabilities of the passive structures to mitigate any level of radioactive releases. Also, the design of the operational controls for the plant rely more on manual or semiautomatic controls than on automatic controls. This leads to the need for a large number of administrative controls to be exercised in the operation of the vitrification plant.

WVDP has put in place a detailed, formal operations program that elaborates on the functions, staff responsibilities and interactions, operating practices, process controls and supporting communications, staff qualifications and training, reporting and record-keeping practices, safety considerations, testing and surveillance, and quality control and quality assessment. The operations program is developed to meet the requirements of DOE Order 5480.19—Conduct of Operations Requirements for DOE Facilities (U.S. Department of Energy, 1990). Based on DOE Order 5480.19 and other industry practices, WVDP has developed a manual, Westinghouse Conduct of Operations Manual, WVDP-106, for the vitrification operations. WVNS has implemented WVDP-106, and it is part of the controlled document system at the site.

A key to the operations program for WVDP is the "graded approach." Here, in the graded approach, the implementation of the scope and depth of any activity is controlled by the anticipated importance and impact on safety, health, and environmental issues. The HLW and waste processing activities have been assigned the highest importance at the site. Significant training is being provided to all the key staff involved in the operations.

> *Evaluation: Administrative controls play an important role in the safe operations of the VP at WVDP. The operations program presented in WVNS-SAR-003 involves major decisional roles for the various operations staff during the conduct of the VP. Many of the staff will perform key safety-related tasks. The risks of not executing any of the staff roles have not been assessed in the WVNS-SAR-003 for the operational conditions. However, it is recognized that this will not affect releases resulting from any accident where operator or staff involvement is not considered.*

The graded approach used by the DOE places emphasis on the most critical components or processes in the system and is controlled by WVNS policy (WVNS-110). However, the ALARA program is controlled by other documents, namely, WV-984, ALARA Program and WVDP-010, Radiological Control Manual. Future updates to WVNS-SAR-003 need to describe the hierarchy of the implementation documents such that there is a clear understanding of the operational practices to be followed by the workers at the site.

2.1.4.2 Safety Implications and QA

The project organization in support of the vitrification campaign is organized along functional lines. The technical staff are qualified and trained to support specific job functions for the campaign. Emphasis has been placed on developing a safety culture at the WVNS. Appropriate reporting practices for various activities and abnormal events have been developed. Training on operating procedures are provided to staff. Alarm systems with remote monitoring are in place. The communications within the facility are carried out by public address system, emergency all-page system, radio, and telephone. Hazardous materials at the facility are controlled by DOE Order 5480.4, rules of the U.S. Environmental Protection Agency (EPA) and other governmental agencies, and established industrial practices.

Pre-operational testing and subsequent operations are conducted using Test Instruction Procedures (TIPs), Special Instruction Procedures (SIPs), Hot Operations Test Plan (HOTP), and Standard Operating Procedures (SOPs). SOPs support both cold and hot operations. These procedures are developed, documented, approved, and controlled by the WVNS Policy and Procedures Manual, WVDP-117. The document control program was developed in accordance with ASME-NQA-1 (American Society of Mechanical Engineers, 1989).

WVNS has in place the Safety Review and Unreviewed Safety Questions Programs. Also, it has a comprehensive configuration and document control program. An extensive fire hazard analysis was conducted and a fire protection program was developed.

Evaluation: Chapter 9 of WVNS-SAR-003 concluded that all the evaluation basis accidents (EBAs) analyzed were below the EGs used to assess safety classes. As a result, there are no specific administrative controls needed to support any technical safety requirements. The conclusion is valid because all the confinement barriers used in the analysis were passive.

During operations, the administrative controls for worker radiological safety are appropriate and acceptable considering that the source term is limited and there is intensive training for operations staff and significant access and procedural control during operations. However, it is recommended that, from an ALARA perspective, the reduction of dose rates resulting from the continuous or long-term occupancy of the vitrification CR should be considered.

2.1.4.3 Human Factors

There are several situations during operations or under accident conditions that need human intervention. A major part of the vitrification operation is also controlled by human action.

Evaluation: While training and personnel development programs are in place, there are opportunities for man–machine interface problems. Cases are identified below where improvements in operations can be made.

- *To support the EBAs analyses, there are scenarios that require operator actions before the standard 2-hr specification for any action (e.g., loss of CFMT vent condenser cooling, SFCM off-gas jumper failure). Here, special training for personnel or mitigating conditions should be identified.*

- *The main plant CR is not continuously monitored. Remote video and audible alarms are provided. Here, the responsibilities of the various personnel and the action party need to be specified.*

- *The equipment operations for the turntable and the transfer of solutions from the CCB to the VC are not controlled from the CR. Here, the communication and coordination between the various operators have to be examined closely and may need a special training program.*

2.2 WASTE MANAGEMENT

The vitrification operations generate gaseous, liquid, and solid wastes. The approach taken by the WVDP to manage these wastes, in particular the radiological wastes, is the subject of discussion in this subsection.

In the VP, the conversion of liquid wastes from Tank 8D-2 to a solid form is considered as the primary product of the operations, and not as a waste. The handling of the HLW generated from this operation is recycled through the system by design. This is the primary mode of waste minimization.

2.2.1 Gaseous Wastes

Off-gas is the main source of waste resulting from the vitrification operations. During normal operations there are no expected off-gas releases at the pump pits near the WTF where the HLW sludge is transferred by pumps to the transfer piping. From this point on, the generation and transport of the off-gases is fully contained within process tanks and piping before any release to the atmosphere via the stacks. The main source of off-gas is at the SFCM. The off-gas from the SFCM is processed through the SBS and mist eliminator and then combined with off-gases from the CFMT, the MFHT, and neutralizing tanks. Before any off-gas is released to the stack there are filtration and drying systems to trap and minimize releases to the environment. To ensure containment of the off-gas within the transport system in the in-cell area, a slight vacuum is maintained in the system. Redundancy in the off-gas treatment equipment exists, primarily to facilitate maintenance functions.

The HVAC system in the VC is designed to operate during design basis accidents (DBAs). The design is such as to provide a flow into the VC and limit any outside releases. Operational doses to personnel are also minimized by incorporating appropriate design features for the filters. Redundancy is also provided in the filter system to prevent unfiltered transport or backflow of gaseous radioactive materials.

Evaluation: The off-gas system layout with parallel filtration trains provides an adequate means to maintain a controlled flow path for the movement of off-gases during the VP. The off-gas system design assists in the minimization of gaseous releases through the stack. Based on the data provided in Table C.6.2.3-1 of WVNS-SAR-003, the concentrations of radionuclides and the associated maximum annual releases from the stack are small under operating conditions. The levels shown are much less than that permitted under 10 CFR 72.104 and 10 CFR Part 20 Appendix B Table 2 (Air Effluent Concentrations) criteria for individuals beyond the controlled area.

The radionuclide particles captured in the various filters in the off-gas stream are treated as part of the solid waste disposal aspect of the project.

2.2.2 Liquid Wastes

Liquid wastes are generated as part of the activities in the waste header system, condensates from the CFMT and other in-cell process vessels, rinse water from the canister decontamination system, and ex-cell off-gas condensates that collect in the VF drains. The HLW components of the waste are cycled back into Tank 8D-2, while the LLWs are treated as part of the integrated radwaste treatment system program or is processed through the LLW treatment facility.

Evaluation: WVNS-SAR-003 describes the waste handling process for the liquid wastes adequately. However, there is no quantitative information about the expected levels of liquid waste that is generated per batch operation during waste vitrification. The LLW generated is classified as per 10 CFR Part 61, and a large quantity will be Class A type. The disposal of residual waste heels in the waste tanks at the end of the vitrification campaign has not been presented in the WVNS-SAR-003. This should be addressed in a future WVNS-SAR-003 update and treated as part of the decontamination and decommissioning plan.

2.2.3 Solid Wastes

The inventory of solid wastes will contain clothing and other anticontamination material used during the vitrification campaign. It will also include contaminated laboratory samples and containers, failed metal and nonmetal components from hot operations area, and spent off-gas and ventilation filters. West Valley has existing facilities to provide temporary storage for these materials. These materials contain Class A, B, and C LLW.

Evaluation: Existing Lag Storage Facility at West Valley can provide temporary storage for the solid LLW. Estimates of the quantities of the waste needs to be addressed in the WVNS-SAR-003 to ensure the adequacy of the storage and handling capacity of the solid waste generated during the period of vitrification. It is recommended that a plan for the removal and disposal of these materials will be addressed in a future update of this WVNS-SAR-003 or in a new one.

2.3 OPERATIONAL DOSES

WVDP has approached the radiological dose issue on a defense-in-depth basis. The layers of defense assumed for the vitrification operations include; passive confinement barriers, wasteform and limited inventory of waste at any given time, active confinement barriers, alarms and monitors, personnel training, and administrative planning and controls. The important passive barriers for the vitrification operation are the thick concrete cell and shielding walls. Limiting the amount of waste processed at any time keeps the source term controlled and thus supports the ALARA program at the facility. Active confinement is provided by ventilation and off-gas systems. Here, the system is designed to control the direction of flow of contaminants and minimize the airborne radioactive components. Alarms and monitors are placed in strategic locations to provide warnings as well as continuous data on any leaks in the process systems. Section 8 of the WVNS-SAR-003 presents a series of internal WVDP guidelines and documents for the radiological safety considerations during operations at the site. These documents reflect requirements of various DOE orders as well as industry practices adapted from the nuclear power generating industry. The documents provide both personnel training requirements as well as administrative controls.

2.3.1 Radiological—On-Site

WVNS uses DOE Order 5480.11 for evaluating on-site radiological hazards. The VF is designed to be below the values described in the DOE order. Furthermore, as an operational strategy, the personnel doses are limited to one-tenth the depicted levels. The lower levels are attained partly by design and partly by administrative controls. The doses within the VC were calculated using the ISOSHLD computer code in conjunction with DOT-3.5 (DiBiase, 1986a,b). During operations, the VC is sealed and no human entry is permitted. The calculated dose rates adjacent to the cell indicate that the maximum dose rates below the 120-ft level is 0.023 mrem/hr while the highest was estimated at the 130-ft level of 3.6 mrem/hr. The design criteria is 0.31 mrem/hr for an assumed 8-hr shift operation. Administrative controls are planned to limit doses to personnel in the higher radiation areas.

There are no on-site airborne or liquid releases anticipated during operations. However, alarms are set at 0.25 mrem/hr at points of continuous occupancy, and at 2.5 mrem/hr at intermittent occupied areas.

Evaluation: The principal criterion used for on-site radiation control is limiting the worker annual dose to 500 mrem. This criterion is one-tenth the occupational total annual effective dose limit specified in 10 CFR Part 20. The criterion used for the on-site radiation limits is conservative. However, parts of the operating aisles of the VC will require limitations to be placed on the time of occupancy to remain in compliance with the WVDP criteria. The WVNS-SAR-003 has not attempted to identify specific locations where the criterion will not be met. It is recommended that shielding calculations be performed for the areas where penetrations or local change in wall geometry can cause higher dose rates. Such results will be useful in developing appropriate survey locations and possible additional barriers if deemed necessary.

2.3.2 Radiological—Off-Site

The main sources of off-site radiation during operations comes from the off-gas system and the VB HVAC system. Only a small amount of radioactivity gets carried to the two stacks. The areas with potential airborne radioactivity are ventilated in a controlled manner such that confinement of contaminants is expected. The estimated maximum dose for an off-site individual during 1 yr of operation of the HVAC system is 9.5×10^{-4} mrem and 0.2 mrem/yr for off-gas releases.

Evaluation: The calculated annual releases from airborne and liquid sources at the site boundary resulting from normal operations is small (i.e., less than 1.3 mrem). It is significantly below the annual, 25 mrem level prescribed in 10 CFR Part 72 for 'any real individual who is located beyond the controlled area.'

2.4 ACCIDENT ANALYSIS

Section 2.1 of this SER discussed in detail the types of hazards, the design of the various systems, the design margins of safety, the defense-in-depth issues, the VP considerations, and the potential for radioactive releases. In this section, an evaluation is made of the accidents considered in Chapter 9 of the WVNS-SAR-003, and the resulting radiological consequences. The purpose is to determine if there is adequate protection for the public and the on-site worker from credible accidents. To exercise judgment on the adequacy of the protection needed, the WVNS-SAR-003 has provided a set of EGs. The EGs cover both radiological as well as non-radiological accidents. The discussions in this section relate only to the radiologically important aspects of credible accidents.

2.4.1 Accident Analysis Evaluation Guidelines

As part of the safety analysis, the consequences of the various accidents considered in the analysis are compared to a set of criteria, referred to as EGs. The EGs for radiological hazards to the public (outside the controlled area) and to on-site personnel are presented in Figures 2-9 and 2-10, respectively. The EGs are based on the frequency of the hazard under consideration. In the calculations performed by WVNS for the consequence analysis, only the passive confinement barriers were used.

Evaluation: The NRC regulations, 10 CFR Part 20, 10 CFR Part 72, and 10 CFR Part 100, have deterministic values for doses for on-site and off-site applications. However, the classification of accidents as anticipated (probability > 10^{-2}/yr), unlikely (probability 10^{-4}/yr to 10^{-2}/yr), extremely unlikely (probability 10^{-6}/yr to 10^{-4}/yr), and incredible (probability < 10^{-6}/yr) based on Elder et al. (1986) and used in WVNS-SAR-003 is generally acceptable and consistent with industry practice. These probabilities are also consistent with NUREG 1150 (Nuclear Regulatory Commission, 1989), where they are used as initiating accident probabilities. For the vitrification operations, the WVNS-SAR-003 has classified the various accidents on a qualitative basis, and the real distinction is between nature- caused accidents versus human-induced events.

The public or off-site radiological criteria in Figure 2-9 have direct links with 10 CFR Part 100 and 10 CFR Part 72 for the extremely unlikely and unlikely categories, while

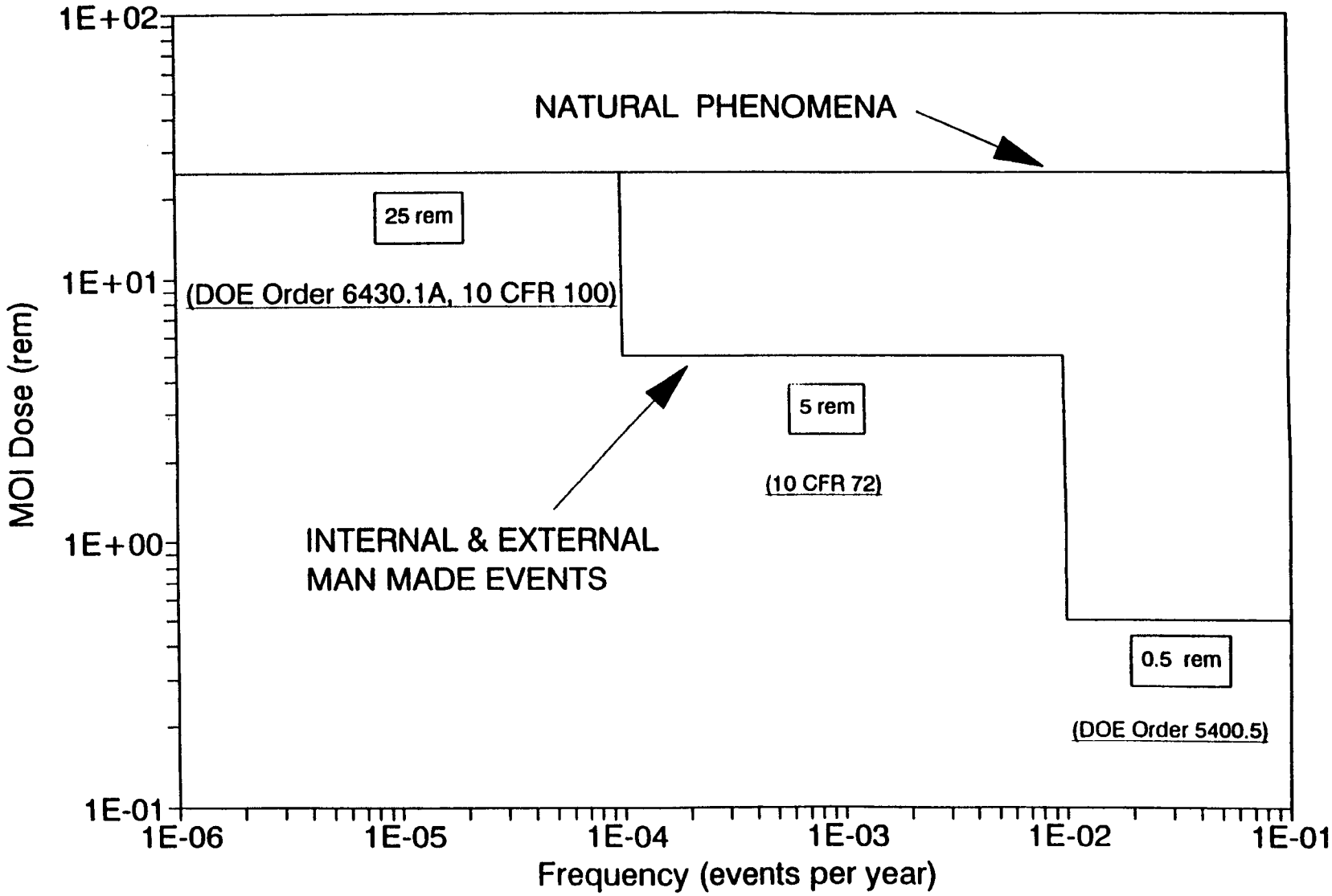


Figure 2-9. Public radiological evaluation guidelines (WVNS-SAR-003, Rev. 2, Draft D, Fig. C.2-1)

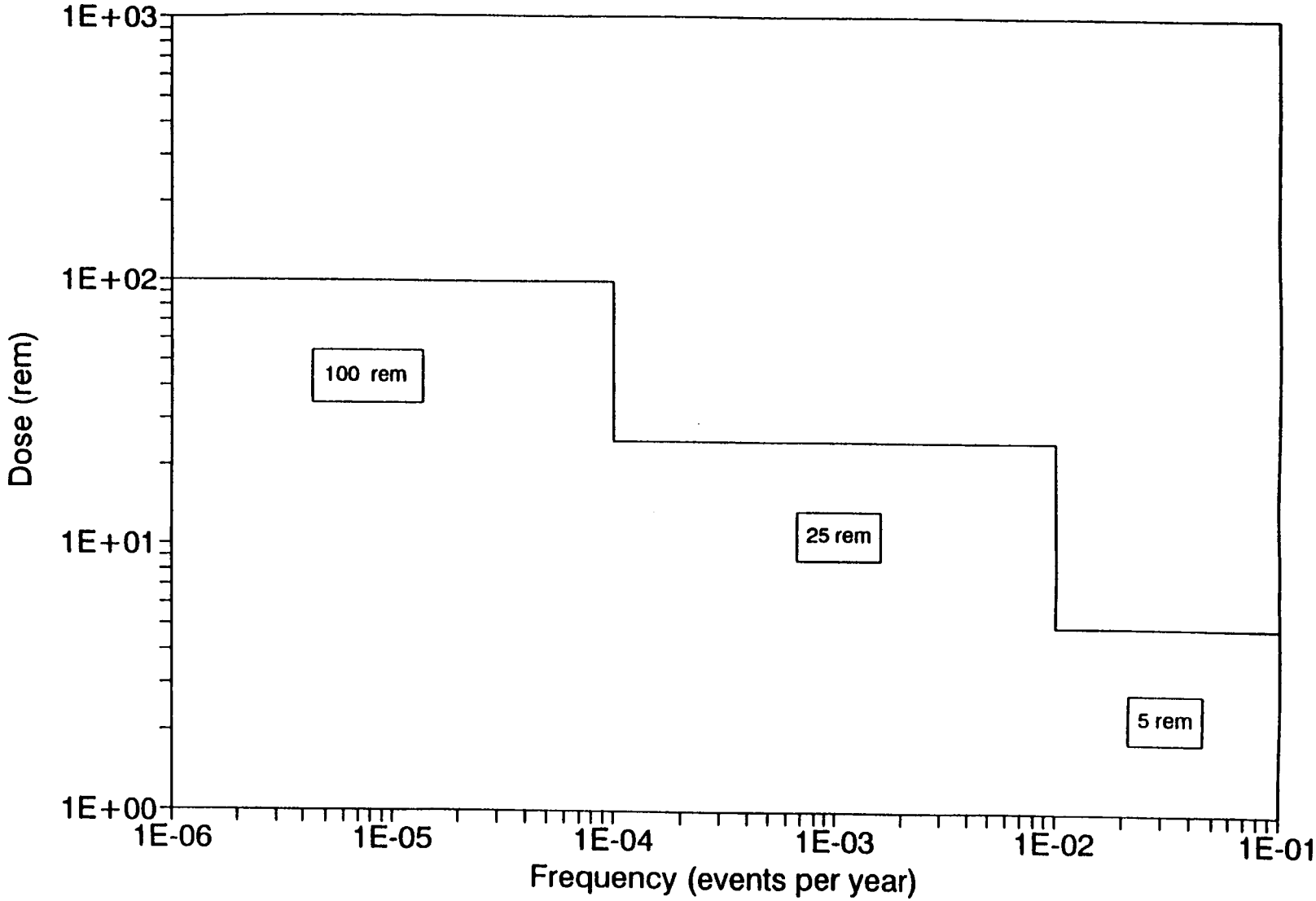


Figure 2-10. On-site radiological evaluation guidelines (WVNS-SAR-003, Rev. 2, Draft D, Fig. C.2-2)

the dose limit for anticipated accidents is compatible with the operational limit of 0.5 rem/yr in 10 CFR Part 20.

The on-site radiological criteria in Figure 2-10 bases the releases at a 640-meter point from the source at the site. The selection of the evaluation point of 640 meters has not been adequately explained. Currently, there is no guidance within the NRC regulations to specify a distance point for evaluating doses. For the human-induced accidents in the anticipated and unlikely accident categories, the 10 CFR Part 20 and 10 CFR Part 100 dose rates are appropriate and are used in the EG. For the extremely unlikely case, a value of 100 rem is assumed. The WVNS-SAR-003 discusses the health effects of on-site personnel dose for this level. NRC does not have a general acceptance level of 100 rem in the regulations. It is recommended that additional measures be taken with regard to site personnel training and administrative controls to minimize personnel doses during plant operations.

2.4.2 Process Hazard Analysis

Section 9 of the WVNS-SAR-003 presents a summary of a PHA performed to identify potential sources of hazard and component or system failures during the VP operations, in Tables C.9.3-1 through C.9.3-7. The tables also describe the mitigative features as well as the consequences of the component or system failures. A Failure Modes and Effects Analysis (FMEA) was also performed. The PHA is qualitative in nature. To develop the consequences of the accident analyses, no credit for airborne releases was assigned to the HEPA filtration. The PHA was conducted for the following systems or components:

- HLW transfer trench, pump pit, and diversion pit
- VF
- Waste canister transfer tunnel
- HLWIS
- CCB
- Off-gas trench and 01-14 Building
- Vitrification support systems from the main plant

There were 24 hazards and 31 causes that were radiologically related in the PHA. Out of the 31 causes, 8 were further evaluated for on-site and off-site releases. The potential hazard with respect to transfers of HLW from Tank 8D-2 to the VC was found to be small. Any leak in the piping is contained by multiple confinement barriers. Leaks or complete failures of the CFMT, the MFHT, or the SFCM have the highest potential source term for releases when they are fully loaded with HLW. HEPA blow-outs also provide a larger constant volume of airborne radiological releases. HLW canister and HLWIS failures do not provide a significant source term for releases. The PHA also addressed in-cell and ex-cell fire issues.

Evaluation: The PHA conducted for the VP is adequate for the purpose of identifying key hazards and representing the consequences. However, the qualitative assessments of frequencies for the various causes have not been established by any data or test results. The batch operation of the VP limits the source term to the maximum capacities of the CFMT, the MFHT, and the SFCM. Based on the curie content and the energetics of the system at any given time, the source term is limited for both airborne and liquid releases. The protection and mitigating systems associated with the hazards are found reasonable based on the review of the in-cell design features and the operational constraints presented in WVNS-SAR-003.

2.4.3 Radiological Evaluation Basis Accidents

The structures and components important to safety were designed, in general, with a margin of safety in excess of 2 against a DBE. The tornado analysis DBT was limited in the VC design to an annual return frequency of 10^{-6}. In this section the consequences of radiological releases from the EBAs are evaluated for various failure scenarios. As discussed in Section 2.4.2, the liquid waste combined with the high energy content molten glass provides the predominant dispersive source term for releases. In the analysis presented in WVNS-SAR-003, the failure of the CMFT with an inventory of concentrated slurry is one of the most severe of the accidents considered, since it represents the highest source term available for dispersion. The consequences of the accidents were evaluated, in terms of a dose to a "reference man," for on-site at 640 m from the source and for off-site at the site boundary. Americium-241 was calculated to be responsible for about 60 percent of the dose from a combined SFCM off-gas release and a CFMT spill. The calculations use dispersion parameters from DOE Standards based on adoption of NRC requirements in 10 CFR Part 30. The analysis has conservatively assumed a ground-level release and a lower value of wind speed of 1 m/sec.

WVNS-SAR-003 presents consequence analysis for 11 accidents or events. These are listed below.

- CFMT slurry release
- Loss of CFMT vent condenser cooling
- SFCM off-gas jumper failure
- Molten glass spill from SFCM
- Steam explosion in the SFCM
- HLW canister drop
- Blow-out of VC HEPA filters
  - Process HEPA blow-out
  - HVAC HEPA blow-out
- Loss of VC coolers

- Loss of VF power
- Design basis tornado
- Inadvertent nuclear criticality

The calculations show that the highest doses for both off-site and on-site are associated with the cases with CFMT and/or SFCM related failures. The maximum calculated EDE is 0.17 mrem with HEPA filtration in place and 17 rem without HEPA filtration for on-site doses, while at the site boundary it is 0.07 mrem with HEPA filtration and 7 rem without HEPA filtration. The higher values of EDE without HEPA filtration are short duration events where the condition is either inventory-limited or operator action takes place within a prescribed time.

Information is presented in the WVNS-SAR-003 on the potential for inadvertent nuclear criticality from concentration of the fissile material. The analysis suggests that a concentration factor of 20 would be needed before criticality limits are exceeded.

Evaluation: The list of EBA and events analyzed is appropriate and covers a broad spectrum. The assumptions and parametric values used in the calculations are conservative and in many cases bounding. The CFMT slurry release, the SFCM off-gas jumper failure, and the steam explosion in the SFCM events are the principal accident scenarios for the vitrification operations. The frequency of occurrence for both the filtered and unfiltered releases in WVNS-SAR-003, Table C.9.4-1, are assumed to be the same. Accounting for the failure probability of the HEPA filters in the analysis would provide a realistic assessment of the nature of the accident and help better define the operator action needs.

The HLW canister drop and the blow-out of the VC HEPA filters have been adequately analyzed and the calculated releases are within the EGs.

The potential concentration of fissile material by chemical, thermodynamical and mechanical means was shown to be remote. The evaluation based on the use of industry standard computer codes is acceptable with the recommendation that a plan to monitor the homogeneity of the feed and a plan for the in-service inspection of key components be considered.

2.4.4 Beyond Design Basis Accidents

For the DBE, the return frequency assumed was 5×10^{-4}/yr. The resulting dose calculations indicate a significant margin in meeting the EGs. The DBT already is associated with a return frequency of 10^{-6}/yr, the limit of the credible range. The BDBA analysis evaluates additional scenarios for a higher level of earthquake or tornado than that assumed in the design. The absolute intensity of the BDBA is not the controlling factor, since any value with a return frequency of 10^{-6}/yr is expected to meet the requirements of the EGs. Based on the margins of safety discussed in WVNS-SAR-003, Section 5, the potential for additional failure scenarios was considered for evaluating the BDBE. No changes were considered for BDBT. Five additional scenarios were considered and their radiological consequences evaluated. They include:

- Loss of all power and cell inlet filters
- SFCM Slurry and CFMT molten glass dump with and without cell ventilation
- Failure of HLWIS roof
- Crane falls in HLWIS
- CFMT steam and slurry release

The calculated doses are the highest for the simultaneous dump of the inventory of the SFCM and the CFMT with continued operation after the HEPA failure. The values are still below the EGs.

Evaluation: The calculated off-site and on-site doses for BDBA are below EG levels and are acceptable. Conservative assumptions used in the calculations provide added assurance for the radiological safety of the operations of the vitrification facility.

3 OTHER SAFETY CONSIDERATIONS

In this section, a review and evaluation of issues and considerations not discussed in Section 2, but germane to the overall safe operations of the vitrification campaign, are presented. It should be noted that several issues and information needs raised in the review of the early versions of the WVNS-SAR-003 by the Joint Review Group, and the respective WVNS responses, have been documented in the Review Comment Record (RCR #SAR-TRG-FR-WV-008,RO) dated December 29, 1994. Those issues resolved in the RCR and not specifically presented in the WVNS-SAR-003, Revision D, are not discussed here.

3.1 OTHER DESIGN AND OPERATIONAL FEATURES

The primary thrusts related to safety of the vitrification campaign are the design against potential hazards and a well-managed operation at the site, discussed in Section 2 of this report. However, there are site and operations related aspects that also contribute to safety. These include the following:

- Surface and Subsurface Hydrology—The VF is built at least 14 ft above potential flood levels (West Valley Nuclear Services Co., Inc. 1994a).

- Effect of Nearby Industrial or Other Facilities—The site location and its distance from any other major facilities are such that they do not restrict or compromise the operations at WVDP.

- Fire Protection—Basically, the VF has been built to the National Fire Protection Association (NFPA) codes. A detailed fire hazard analysis was performed for the VF. The design attempts to minimize potential for fire and has automatic fire suppression systems and other fire protection systems. Fire-resistant and non-combustible materials have been used in construction. Automatic fire detection instrumentation and fire alarms have been installed.

- Non-Radiological Effects—The non-radiological events or contaminations do not directly contribute to any radiological problems at the site. However, a rupture in the ammonia supply/injection system may produce some damage to 01-14 Building or affect the HVAC in the ex-cell area.

- Backup, Standby, and Redundant Systems—Backup is provided for normal power outages. The design is such that common mode failures or power failures do not affect the backup power source functions. A diesel generator provides standby capability for the HVAC system. Redundant systems are incorporated into the VF to support operations.

- Control Systems—There are both automatic and manual controls for the VF operations. The VP is computer controlled from the VF CR. Alarm settings and set point changes are fed through the data collection and control system. There are also interlocks to control key process parameters and backflow of materials. Besides the computer-controlled operations in the VC, there are manually controlled operations for processing chemicals in the CCB and subsequently transporting them to the VC. The manual operations interfacing with the VC and the storage and disposal of hazardous materials are all controlled by administrative procedures.

- QA—WVDP implements a site-wide QA program in compliance with QA Requirements and Description, DOE/RW-0333P (U.S. Department of Energy, 1992b). This DOE document is based on Quality Assurance Program Requirements for Nuclear Facilities, ASME-NQA-1 (American Society of Mechanical Engineers, 1989). The details of the QA program are in WVNS-SAR-001 and not in WVNS-SAR-003.

- Training—An important activity at the site is training site personnel. Training programs have been developed for both in-classroom study as well as on the job training. The training covers a wide scope of activities, including technical safety requirements, standard operating practices, and administrative and emergency preparedness.

- Emergency Planning—WVNS has developed a detailed site-emergency plan in the WVDP Emergency Plan Manual, WVDP-022. The plan provides a description of the preparedness and response program to deal with all emergencies at the site and the mitigation of consequences both on-site and off-site. The plan also outlines the communication and notification aspects of the program and defines the role and responsibilities of the various personnel and organizations.

Evaluation: The WVNS-SAR-003 describes the design and operational features in detail in several sections. The analyses provided in the WVNS-SAR-003 for mitigating the consequences for fire and other hazards are based on the initiating event only. In many instances, the initiating event may be of low consequence. However, if a failure-effects tree were to be developed, additional or alternate mitigative action would be taken. It is recommended that, as part of the operational readiness review, an examination of a second or third level of the failure modes be undertaken.

In the case of backup and redundant systems, care should be taken to ensure that these systems are indeed available at all times during operations and not shut down for any maintenance operation. An example of a potential situation is when one of the two parallel filter trains in the off-gas system is off line for service. The diesel generator provides spare capacity to run the HVAC system during an electrical outage.

There are independent controls for the operations of the CCB and the VC. The main interface, outside of the alarm system are administrative controls. There is a potential for human error in this area. It is recommended that special training be provided to the operators to ensure adequate coordination.

3.2 SPECIAL STUDIES

During the process of NRC review of the WVDP activities pertaining to the vitrification campaign, there were three areas that have been the subject of detailed discussion with WVNS. They include: criticality, corrosion, and seismic re-evaluations.

3.2.1 Criticality

WVDP has in place a Criticality Safety Program Plan, WVDP-162. This document provides the criteria and the margins of safety for maintaining subcritical conditions at the site. Currently, the slurry in Tank 8D-2 contains uranium and plutonium as insoluble salts. The fissile material has, to date, remained uniformly dispersed within the tank. It is the intent to process a limited quantity of HLW from the tank at a time and transport it to the VC. The slurry from Tank 8D-2 will be mixed well by the pumps and homogenized before the transport. Once the slurry mixed with the chemicals is introduced in the CFMT and MFHT, the uranium dioxide or uranium hydroxide is reduced to uranium dioxide at elevated temperatures. The form of plutonium (i.e., plutonium dioxide) does not undergo any changes as a result of temperatures in the anticipated range. Carl et al. (1990) studies indicate that no isotopic enrichment or depletion is expected as a result of the VP. The maximum reactivity of HLW solids in the CFMT was evaluated as a function of water. The calculated maximum K_{eff} was shown to be less than 0.08.

Evaluation: The calculated K_{eff} is based on the maximum inventory at any given time in the CFMT. Also, a key assumption is that the HLW feed remains homogenous during the VP. These assumptions do not preclude the possibility of fissile material plating out in the CFMT and in the connecting piping. Over a period of operation, this could lead to accumulation of fissile material. It is recommended that mass balance at various points in the system be checked periodically during the period of the vitrification campaign. Also, it may be prudent to inspect the CFMT and other components for plating of fissile materials at least once during the campaign, if an opportunity arises.

3.2.2 Corrosion

The in-cell and the ex-cell equipment have a design life of 7 yr. Based on this consideration, the corrosion life for each nonreplaceable component was determined to be in excess of the needed 7 yr. Other components that have a shorter life or fail in service are expected to be replaced by remote operations. Corrosion allowance is the main design factor. However, to address localized corrosion issues, corrosion resistant materials have been chosen to minimize the corrosion, and a plan is in place for periodic visual inspections. Erosion of materials, especially for ceramic components, has also been considered in design.

Evaluation: The chemical milling to decontaminate the filled HLW canister uses a 0.5 molar nitric acid solution with ceric ion (Ce^{+4}). The unreacted Ce^{+4} is reduced to Ce^{+3} by introducing hydrogen peroxide to minimize corrosion effects on SS components. However, it should be noted that radiolysis of the decontamination liquid in the vicinity of the HLW container may add to the corrosive environment for SS components. It is recommended that the decontaminated liquids be periodically analyzed to identify any corrosion products.

With the batch operations for the VP, there will be only a limited amount of corrosive solution in contact with components at any given time. However, from industrial experience, it has been found that intermittently used 304L SS components are subject to localized corrosion or stress corrosion cracking as a result of stagnant residual

environments, including oxygenated water. It is suggested that inspection of the inside of piping and tank components be conducted at least once after half the campaign is over.

3.2.3 Seismic Re-Evaluations

There are several parts of the VF that were constructed at different times in the last 10 yr and to differing codes and requirements. The VC and associated structures were built solely for the purpose of the vitrification of HLW. The pre-existing structures that form the VF include the EDR, the CPC, the CPC CMR, and the 01-14 Building. The details of the seismic evaluation for these and other structures are presented in Section 2 of this report. WVNS conducted detailed re-evaluation of the seismicity in the local region and developed detailed dynamic models to demonstrate larger margins in structural resistance for these structures.

Evaluation: The seismic re-evaluation of structures based on current codes and standards and using detailed dynamic modeling has provided a good assessment of the conservatism involved in the earlier analyses. The data presented as part of the minutes of the meeting held in February 1995 (Rowland, 1995) recommends the use of an Evaluation Basis Earthquake of 0.078 g using DOE Standards 1020 and 1024. However, the DBE used in the calculations was 0.1 g. This is consistent with the minimum required in 10 CFR Part 72.

3.3 TESTING, MONITORING, AND LEAK DETECTION

Testing is planned in the WVNS-SAR-003 for all the components that support the normal operations of the off-gas and HVAC systems. This typically involves preoperational testing of the wiring, controls, and the functioning of components regulating flow rates. Chilled water chemistries will be periodically checked. The off-gas system is monitored continuously to ensure NOX treatment and particulate filtering are properly functioning. Process samples are taken and analyzed to verify the parameters of the glass product.

WVNS-SAR-003 identifies an important aspect of the VP as the capability to operate a reliable and accurate leak detection system. WVDP uses visual, level measurements, flow meters, and mass balance methods to provide the leak detection capability. The in-cell vessels use a minimum of two leak detection methods to provide information about leaks.

Evaluation: A principal method of inspection and leak detection for the in-cell components is the use of the cell viewing windows. There are also in-cell cameras to view specific locations within the cell. However, there are so many components and hardware items in the cell that a complete visual coverage is not possible. The automatic level detections in the tanks or drains may not be sufficient to provide early warnings of leaks in the system. It is recommended that during preoperational testing, special training be provided to operators on how to conduct visual inspections and what the uncertainty might be for leaks in any given area of the VC.

4 PROGRAMMATIC CONSIDERATIONS

The WVNS-SAR-003 addresses the important aspect of the solidification of liquid HLW as required by the WVDP Act of October 1980. In doing so, the WVNS-SAR-003 interfaces with other processes and activities being conducted at the site. Some of these activities deal with the maintenance of pre-existing site conditions. They include among other activities: HLW tank storage, LLW drum storage, effluent lagoons, site decontamination operations, and wastes processing. Some of the structures and facilities used in these operations are common to several of the activities undertaken. The performance requirements for each of the operations vary for each structure. WVNS has incorporated the structures needed for the VP by reanalyzing some and retrofitting others as appropriate.

The liquid HLW in the storage Tank 8D-2 continues to generate more important safety concerns than the VP. The integrity and safety concerns about the tank farm components were addressed earlier in WVNS-SAR-002, which is currently under revision. The description of the facilities and their functions are described in WVNS-SAR-001. To date, the HLW has been confined to the tank farm. The waste solidification process deals with a small batch at a time and attempts to minimize the safety issues. However, the result of the vitrification campaign will be to move the HLW from the tanks to other parts of the site facilities.

Nonradiological issues, not a direct subject of this SER, play an important role in the conduct of the vitrification operations. Chemicals transported into and out of the site, and also stored on site, would be subject to strict adherence to codes and standards when operating in the area of HLW processing. For example, the ammonia tank near the 01-14 Building is a potential hazard to the ventilation system in the ex-cell area if the tank were to rupture. There are portable monitors at the site to sample air quality with respect to nitrogen oxides and ammonia. These monitors may be appropriate to detect early leaks.

> *Evaluation: In general, the programmatic issues that affect WVNS-SAR-003 have been identified and references provided where there are important interfaces. However, some of the cited references (e.g., WVNS-SAR-002) are themselves undergoing changes. It is recommended that future updates of WVNS-SAR-003 on vitrification attempt to summarize parts of the key information that is currently elsewhere, and to incorporate the information directly into the WVNS-SAR-003. This recommendation would be advisable especially when the schedules of the updates of the various associated SARs do not coincide.*
>
> *The WVNS-SAR-003 has presented the site emergency plans in detail. To successfully implement these plans will require participation in training programs by site personnel not directly associated with the VP. An early training schedule for all personnel on-site is recommended.*
>
> *As part of the corrosion limiting conditions in the design of structural components, corrosion resistant or corrosion allowance materials have been used. It is recommended that a nondestructive examination program be planned for at least once every 3–4 yr for the components in the vitrification, tank farm, and ammonia tank attachment areas. This would provide added assurance regarding integrity of the components, especially if the vitrification campaign is extended.*

5 CONCLUSIONS AND RECOMMENDATIONS

This section presents conclusions derived from the previous sections of the SER. Discussion is provided in the topical areas deemed important to the VF design and operations.

5.1 DESIGN PHILOSOPHY

The design approach for the VF reflects good engineering practice and is based on methodology used historically for facilities with similar or greater hazards. The design philosophy for the VF emphasizes the multiple barriers of confinement of potential radiological releases. The outermost level of confinement is provided by passive confinement structures and components whose continued function under all but incredible conditions is assured by design. Redundancy and/or backup capability are included in the design for high reliability. A "cascading pressure" design feature for ventilation of radiological areas directs air flow so that airborne radiological contaminants are directed from areas of lesser contamination to areas of greater contamination, thereby controlling doses due to airborne radiological materials [similar to 10 CFR Part 72, §72.126(a)].

Active confinement barriers maintain doses and releases to very low levels during normal operations, and their function is needed to ensure that cumulative effects of radiological releases are below allowable levels. The HEPA filtration provided by the VC HVAC and Process Off-Gas Systems minimizes contamination from exiting the VF. Similar HEPA filtration is provided by other ventilation systems active during normal vitrification operations, such as that provided for the HLWIS and the HLWTS. The solid waste form produced by the VP inherently minimizes potential releases due to accidents involving filled HLW canisters.

Appropriate industry standards were used in the design of various components and structures for each safety class and quality level. Policies, procedures, and guidance affecting design control are consistent with ASME-NQA-1 (American Society of Mechanical Engineers, 1989) and reflect good design practice. The graded approach to assigning safety classification and quality levels has been presented in WVNS-SAR-001, and it originates from a widely recognized, basic nuclear QA program standard (ASME-NQA-1). Limiting Safety Class B to primary confinement and VC HVAC components follows the safety classification criteria presented in WVNS-204.

Components and systems were evaluated against these design concepts and standards, and components and systems were found to consistently incorporate them appropriately. One exception is the installation of two parallel HVAC exhaust fans, for which no redundant fan would be available if one fan were inoperable due to maintenance or replacement.

5.2 SEISMIC ANALYSIS

The normal operational loads and the severe environmental loads defined for the VF conform with standard engineering practice. For the majority of structures, systems, and components, these loads are bounded by tornado and earthquake conditions. The procedures used to combine these extreme environmental loads with other loads conform with standard engineering practice.

The basic procedures used in the seismic design and analysis of the individual components and equipment was in accordance with standard engineering practice applicable at the time. The re-evaluation

of seismic response of structures is based on current codes and standards. The detailed dynamic modeling in the re-evaluation provided a good assessment of the conservatism involved in the earlier analyses. The DBE used in the design was 0.1 g, with an annual probability of exceedance of 5×10^{-4}. The evaluation basis earthquake recommended by WVDP as a result of using DOE Standards 1020 (U.S. Department of Energy, 1994) and 1024 (U.S. Department of Energy, 1992a) was 0.078 g, with an annual probability of exceedance of 5×10^{-4}. It should be noted that 10 CFR Part 72 specifies a minimum value of 0.1 g for design purposes. Also, the values for soil and composite damping for the VF are acceptable based on the soil-structure interaction analysis that was performed and information provided in the February 1995 meeting (Rowland, 1995). The soil-structure interaction analysis of the overall response of the VF has been performed in accordance with the state-of-the-art procedures.

5.2.1 Seismic Analysis for Confinement Barriers

The population of structures, systems, and components considered for seismic loading in the WVNS-SAR-003 includes most of those that are important to active and passive confinement. Exceptions include the following components of the HLWTS: (i) the Pump Pits 8Q-1 and 8Q-4; (ii) the buried double-walled steel pipe from those two pits; and (iii) the steel-covered portion of the HLW Pipe Trench. Although these omissions in WVNS-SAR-003 do not create a safety risk, it is recommended that they either be included in future revisions of the SAR or that future SAR revisions indicate the document in which safety aspects related to the three components are addressed. The major structural elements of the confinement barriers, including the roof, wall, and mat, have margins of safety greater than 3.5×DBE.

In addition to structural failure, the potential for contact between the VF cell and the EDR of the existing Nuclear Fuel Reprocessing Plant was calculated, and the maximum closure was 0.8 in. The resulting margins of safety are acceptable. The existing stack does not appear to pose any problem to the confinement barriers.

The special doors have margins of safety that are acceptable for both the earthquake and tornado design basis events. Appropriate failure modes have been included in the analysis. The margin of safety for the shield windows associated with the earthquake event was greater than 3.0×DBE.

The primary concern for the hatches on the VC and the CMR roof is uplift during the seismic events, and the margin of safety for this event is greater than 6.0×DBE. Consideration of the appropriate failure modes has been included in the analysis.

The lowest margin of safety for the five penetrations considered was greater than 2.5×DBE, where penetration failure was considered for relative motion of various portions of the penetrations as well as the potential for shearing due to impact of other structures and components. Most penetrations are designed with shut-off valves and other passive systems that will reduce the amount of release to acceptable levels. Appropriate failure modes were considered in the analysis.

5.2.2 Seismic Analysis for Other Structures, Systems, and Components

Margins of safety against the DBE for other structures, systems, and components are acceptable, and they have been re-evaluated for certain important structures for which margins were relatively low by previous analysis. In particular, margins for the process tanks and tank support frame were re-evaluated to be greater than 2.0×DBE and 2.2×DBE, respectively (previous values were greater than

1.7×DBE and 1.4×DBE, respectively). Margins of safety indicate that no component or structure analyzed will fail at the DBE, and only four have margins less than 2×DBE. Three of these (overhead crane, margin greater than 1.7×DBE; canister decontamination station, margin greater than 1.9×DBE; and canister weld station, margin greater than 1.8×DBE) do not represent confinement barriers. The fourth, the process off-gas structure (margin greater than 1.7×DBE), does not provide passive confinement, and its failure will not result in exceedance of EGs, per accident analysis.

5.3 ANALYSIS FOR MARGINS AGAINST TORNADOES AND TORNADO-GENERATED MISSILES

The basic design procedures for tornado and tornado missiles design considerations are in accordance with standard engineering practice (ANSI/ASCE 7-88). The parameters associated with the DBT and tornado-generated missiles are in conformance with standard engineering practice (McDonald, 1983; American Nuclear Society, 1983; Nuclear Regulatory Commission, 1974), as modified for site-specific conditions.

WVNS was analyzed for missile impact with a probability of exceedance of 1×10^{-6}. At this level, the mass of the missiles was appropriately assumed and is consistent with engineering practice for NPPs. The conclusion that there will be no releases resulting from the missiles is acceptable, based on the evaluation that the missiles do not directly penetrate any of the in-cell tanks or piping containing HLW.

Passive confinement barriers were appropriately analyzed for margins against the effects of tornadoes and tornado-generated missiles. Reasonable assumptions have been used in calculating the consequences of tornado missiles striking the VC windows. Consideration of the appropriate failure modes has been included in the analysis. The worst case is the impact of the leaded glass windows by a 3-in. diameter steel pipe traveling at 50 mph. Although failure of one of the windows is possible due to the missile impact, the probability of occurrence is remote (estimated to be 10^{-10}) and the releases below acceptable levels.

5.4 ADMINISTRATIVE CONTROL

Administrative controls play an important role in the safe operations of the VP at WVDP. The operations program presented in WVNS-SAR-003 involves major decisional roles for the various operations staff during the conduct of the VP. Many of the staff will perform key safety related tasks. The risks of not executing any of the staff roles have not been assessed in the WVNS-SAR-003 for the operational conditions. However, it is recognized that this will not affect releases resulting from any accident, where operator or staff involvement are not considered.

The "graded approach" used by DOE places emphasis on the most critical components or processes in the system and is controlled by WVNS policy (WVNS-110). However, the ALARA program is controlled by other documents, namely, WV-984, ALARA Program, and WVDP-010, Radiological Control Manual. Future updates to WVNS-SAR-003 need to describe the hierarchy of the implementation documents such that there is a clear understanding of the operational practices to be followed by the workers at the site.

Opportunities exist for improvements in operations with respect to administrative control. For scenarios in which operator actions are needed within a 2-hr period after an evaluation basis accident, special training for personnel or mitigative conditions should be identified. Responsibilities of various personnel in the main plant CR need to be specified. The communication and coordination between the various operators for turntable operations and for transfer of solutions from the CCB to the VC deserve special review to determine if a special training program is needed. For in-cell operations that require visual observation through the viewing windows or by video monitors, special training may be needed on how to conduct visual inspections (e.g., to detect leaks via backup level detection) when complete visual coverage is not possible.

Implementation of site emergency plans will require significant participation in training programs for personnel at the site that are not directly associated with the VP, and an early training schedule for all on-site personnel is recommended.

5.5 WASTE STREAMS

Estimates of the quantities of the waste (such as spent HEPA filters from the off-gas and HVAC systems) need to be addressed in the WVNS-SAR-003 to ensure the adequacy of the storage and handling capacity for the wastes generated during the period of vitrification. It is recommended that a plan for the removal and disposal of these materials be addressed in a future update of this WVNS-SAR-003 or in a new one. Liquid radiological waste (e.g., a melter feed batch not meeting specifications) is recycled to tank 8D-2 during the VP. Estimates of the quantities of liquid waste generated per batch need to be addressed in the WVNS-SAR-003. Other necessary additions to WVNS-SAR-003 are discussions on disposition of (i) greater-than-class C waste after recycling of liquid waste through Tank 8D-2 ends; and (ii) decontamination liquids that require specialized storage for TRU wastes.

5.6 RADIOLOGICAL ON-SITE AND OFF-SITE DOSES

Comparisons of on-site and off-site dose criteria for WVDP with corresponding values from NRC regulations indicates that they provide similar levels of protection to the public and to on-site workers.

The public, or off-site, radiological criteria used for WVDP design have direct links with 10 CFR Part 100 and 10 CFR Part 72 for the extremely unlikely and unlikely categories while the dose limit for anticipated accidents are compatible with the operational limit of 0.5 rem/yr in 10 CFR Part 20. The calculated annual releases from airborne and liquids at the site boundary resulting from normal operations is small, less than 1.3 mrem. It is significantly below the annual 25 mrem level prescribed in 10 CFR Part 72 for "any real individual who is located beyond the controlled area." Based on the data provided in Table C.6.2.3-1 of WVNS-SAR-003, the concentrations of radionuclides and the associated maximum annual releases from off-gases from the stack are small under operating conditions. The levels shown are much less than that permitted under 10 CFR 72.104 criteria for individuals beyond the controlled area.

The principal criterion used for on-site radiation control is limiting the worker annual dose to 500 mrem. This criterion is one-tenth the occupational total annual effective dose limit specified in 10 CFR Part 20. The criterion used for the on-site radiation limits is conservative. However, parts of the operating aisles of the VC will require limitations to be placed on the time of occupancy to remain in

compliance with the WVDP criterion. The WVNS-SAR-003 has not attempted to identify specific locations where the criterion will not be met. It is recommended that shielding calculations be performed for the areas where penetrations or local change in wall geometry can cause higher dose rates. Such results will be useful in developing any appropriate survey locations and possible additional barriers if deemed necessary.

The on-site radiological criteria in Figure 2-10 bases the releases at a 640-m point from the source at the site. The selection of the evaluation point of 640 m has not been adequately explained. Currently, there is no guidance within the NRC regulations to specify a distance point for evaluating doses.

For the human-induced accidents in the anticipated and unlikely accident categories, the 10 CFR Part 20 and 10 CFR Part 100 dose rates are appropriate and are used in the EG. For the extremely unlikely case, a value of 100 rem is assumed. The WVNS-SAR-003 discusses the health effects for this level of on-site personnel dose. The NRC does not have a general acceptance level of 100 rem in the regulations, except for special circumstances. It is recommended that additional measures be taken with regard to site personnel training and administrative controls to minimize personnel doses during plant operations.

The NRC regulations, 10 CFR Part 20, 10 CFR Part 72, and 10 CFR Part 100, have deterministic values for doses for on-site and off-site applications. However, the classification of accidents as anticipated (probability $> 10^{-2}$/yr), unlikely (probability 10^{-4}/yr - 10^{-2}/yr), extremely unlikely (probability 10^{-6}/yr - 10^{-4}/yr), and incredible (probability $< 10^{-6}$/yr), based on Elder et al. (1986) and used in WVNS-SAR-003, is generally acceptable and consistent with industry practice. These probabilities are also consistent with NUREG-1150 (Nuclear Regulatory Commission, 1989) where they are used as initiating accident probabilities. For the vitrification operations, the WVNS-SAR-003 has classified the various accidents on a qualitative basis, and the real distinction is between nature-caused accidents versus man-induced events.

5.7 ACCIDENT ANALYSIS

The PHA conducted for the VP is adequate for the purpose of identifying key hazards and representing the consequences. The batch operation of the VP limits the source term to the maximum capacities of the CFMT, MFHT, and SFCM. The protection and mitigating systems associated with the hazards are found reasonable based on the review of the in-cell design features and the operational constraints presented in WVNS-SAR-003. Future revisions of WVNS-SAR-003 should include a discussion on tests for functionality of leak detectors in pump pits and those in the transfer trench.

The list of EBA and events analyzed is appropriate and covers a broad spectrum. The assumptions and parametric values used in the calculations are conservative and, in many cases, bounding. The potential concentration of fissile material by chemical, thermodynamical, and mechanical means was shown to be remote.

The calculated off-site and on-site doses of BDBA are below EG levels and are acceptable. The conservative assumptions made in the calculations provide added assurance for the radiological safety of the operations of the vitrification facility.

5.8 CRITICALITY

The calculated K_{eff} is based on the maximum inventory of homogeneous HLW feed at any given time in the CFMT. The WVNS-SAR-003 needs to address the possibility of fissile material plating out in the CFMT and in the connecting piping that, over a period of operation, could lead to accumulation of fissile material. A mass balance at various points in the system, to be checked periodically during the vitrification campaign, is recommended. It may be prudent to inspect the CFMT and other components for plating of fissile materials at least once in the entire campaign, such as during any planned outages.

5.9 CORROSION

After canister decontamination, the chemical milling solution, which uses a 0.5 molar nitric acid solution with ceric ion (Ce^{+4}), is reduced to Ce^{+3} by introducing hydrogen peroxide, thereby minimizing corrosion effects on SS components. The possibility of radiolysis of the decontamination liquid in the vicinity of the HLW container, which may add to the corrosive environment for SS, suggests that the decontaminated liquids be periodically analyzed to identify any corrosion products.

For process vessels and piping, the batch operation for the VP limits the amount of available corrosives. Industrial experience indicates that intermittently used SS components are subject to localized corrosion or stress corrosion cracking as a result of stagnant residual environments. It may be prudent to inspect wetted surfaces of piping and tank components at least once during the vitrification campaign.

Materials with corrosion resistance or with adequate thickness for corrosion allowance have been used in the design of structural components, and a nondestructive examination program would provide added assurance of their integrity, especially if the vitrification campaign is extended. It is recommended that such a nondestructive examination program be planned for periodic (e.g., once in 3–4 yr) examination of the components in the vitrification, tank farm, and ammonia tank attachment areas.

6 REFERENCES

American Concrete Institute. 1990. *Code Requirements for Nuclear Safety Related Concrete Structures and Commentary*. ACI 349/349R-90. Detroit, MI: American Concrete Institute.

American Concrete Institute. 1992. *Building Code Requirements for Reinforced Concrete and Commentary*. ACI 318/318R-92. Detroit, MI: American Concrete Institute.

American Institute of Steel Construction. 1984. *Nuclear Facilities—Steel Safety Related Structures for Design, Fabrication and Erection*. AISC S327-84. New York, NY: American Institute of Steel Construction.

American Institute of Steel Construction. 1986. *Specification for Structural Buildings, Load & Resistance Factor Design*. AISC S328-86. New York, NY: American Institute of Steel Construction.

American Institute of Steel Construction. 1989. *Manual of Steel Construction, Allowable Stress Design, Ninth Edition*. AISC M016-89. New York, NY: American Institute of Steel Construction.

American Institute of Steel Construction. 1991. *Manual of Steel Construction, Load & Resistance Factor Design, First Edition*. AISC M015-91. New York, NY: American Institute of Steel Construction.

American Institute of Steel Construction. 1992a. *Manual of Steel Construction, Volume II, Connections, First Edition*. AISC M017-92. New York, NY: American Institute of Steel Construction.

American Institute of Steel Construction. 1992b. *Seismic Provisions for Structural Steel for Buildings*. AISC S341-92. New York, NY: American Institute of Steel Construction.

American National Standards Institute. 1982. *Minimum Design Loads for Buildings and Other Structures*. ANSI A58.1. New York, NY: American National Standards Institute.

American National Standards Institute/American Society of Civil Engineers. 1988. *Minimum Design Loads for Buildings and Other Structures*. ASCE 7-88. New York, NY: American Society of Civil Engineers.

American Nuclear Society. 1981. *Determining Design Basis Flooding at Power Reactor Sites*. ANS-2.8-81. La Grange Park, IL: American Nuclear Society.

American Nuclear Society. 1983. *Standard for Estimating Tornado and Extreme Wind Characteristics at Nuclear Power Plant Sites*. ANS-2.3-83. La Grange Park, IL: American Nuclear Society.

American Society of Civil Engineers. 1980. *Structural Analysis and Design of Nuclear Plant Facilities*. ASCE 58-80. New York, NY: American Society of Civil Engineers.

American Society of Civil Engineers. 1986. *Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures*. ASCE 4-86. New York, NY: American Society of Civil Engineers.

American Society of Mechanical Engineers/American National Standards Institute. 1975. *Testing of Nuclear Air-Cleaning Systems*. ANSI N510-1975. New York, NY: American Society of Mechanical Engineers.

American Society of Mechanical Engineers/American National Standards Institute. 1976. *Nuclear Power Plant Air Cleaning Units and Components*. ANSI N509-1976. New York, NY: American Society of Mechanical Engineers.

American Society of Mechanical Engineers/American National Standards Institute. 1987. *Chemical Plant and Petroleum Refinery Piping*. ASME B31.3-1987. New York, NY: American Society of Mechanical Engineers.

American Society of Mechanical Engineers. 1989. *Quality Assurance Program Requirements for Nuclear Facilities*. ASME NQA-1. New York, NY: American Society of Mechanical Engineers.

Atkinson, G.M. 1993. Notes on ground motion parameters for eastern North America: Duration and H/V ratio. *Bulletin of the Seismological Society of America* 83(2): 587–596.

Bernreuter, D.L., J.B. Savey, R.W. Mensing, and J.C. Chen. 1985. *Seismic Hazard Characterization of the Eastern United States, Vol. 1—Methodology and Results of Ten Sites*. UCID-2042. Livermore, CA: Lawrence Livermore National Laboratory.

Bernreuter, D.L., J.B. Savey, R.W. Mensing, and J.C. Chen. 1989. *Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains*. NUREG/CR-5250. UCID-2151, Vols. 1 and 2. Livermore, CA: Lawrence Livermore National Laboratory.

Boore, D.M., and G.M. Atkinson. 1992. Source spectra for the 1988 Saguenay, Quebec, earthquakes. *Bulletin of the Seismological Society of America* 82(2): 683–719.

Carl, D.E., J. Paul, J.M. Foran, R. Brooks. 1990. *West Valley Demonstration Project Vitrification Process Equipment Functional and Checkout Testing of Systems (FACTS)*. Topical Report DOE/NE/44139-64. West Valley, NY: West Valley Nuclear Services Co., Inc.

Dames & Moore. 1983. *Seismic Hazard Analysis—West Valley Demonstration Project*. Los Angeles, CA: Dames & Moore.

Dames & Moore. 1992. *Seismology: Volume II of Environmental Information Document prepared for U.S. Department of Energy West Valley Project Office by West Valley Nuclear Services, Inc.* Orchard Park, NY: Dames & Moore.

Dames & Moore. 1994a. *Confinement Barrier Integrity Review of Vitrification Facility, West Valley, New York*. Job No. 10805-866-004. Los Angeles, CA: Dames & Moore.

Dames & Moore. 1994b. *Confinement Barrier Integrity Review High Level Waste Transfer Piping, West Valley, New York*. Job No. 10805-867-004. Los Angeles, CA: Dames & Moore.

Dames & Moore. 1994c. *Confinement Barrier Integrity Review of Vitrification Facility—West Valley Demonstration Project—for West Valley Nuclear Services Company, Inc.* Job No. 10805-867-004. Los Angeles, CA: Dames & Moore.

Dames & Moore. 1994d. *Integrity Review of Seismically Hazardous Components and Equipment—Vitrification Facility—West Valley Demonstration Project for West Valley Nuclear Services Company, Inc.* Job No. 10805-866-004. Los Angeles, CA: Dames & Moore.

Dames & Moore. 1995. *Evaluation of Ground Motion Hazard at the West Valley Demonstration Project Site, West Valley, New York.* Job No. 10805-966-005. Los Angeles, CA: Dames & Moore.

DiBiase, R. 1986a. *Shielding Analysis: CTS Conversion.* Letter to K.A. O'Ahoofe. HG:86:0035. West Valley, NY: West Valley Nuclear Services Co., Inc.

DiBiase, R. 1986b. *Shielding Analysis: CTS Conversion with Attachment.* Letter to K.A. O'Ahoofe. HG:86:0047. West Valley, NY: West Valley Nuclear Services Co., Inc.

Elder, J.C., J.M. Graf, J.M. Dewart, T.E. Buhl, W.J. Wenzel, L.J. Walker, and A.K. Stoker. 1986. *A Guide to Radiological Accident Considerations for Siting and Design of DOE Nonreactor Nuclear Facilities.* LA-10294-MS. UC-41. Los Alamos, NM: Los Alamos National Laboratory.

Electric Power Research Institute. 1986. *Seismic Hazard Methodology for the Central and Eastern United States.* Report NP-4726. Palo Alto, CA: Electric Power Research Institute: Vols. 5–10.

Electric Power Research Institute. 1989. *Probabilistic Seismic Hazard Evaluation of Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue.* Report NP-6395-D. Palo Alto, CA: Electric Power Research Institute.

Electric Power Research Institute. 1993. *Guidelines for Determining Design Basis Ground Motions, Volume 1: Method and Guidelines for Estimating Earthquake Ground Motion in Eastern North America.* EPRI TR-102293. Palo Alto, CA: Electric Power Research Institute.

Gates, W.E., A.R. Porush, and R.W. Kupp. 1989. *Tornado-Driven Missile Penetration Resistance of Shield Windows on Vitrification Cell for West Valley Nuclear Services Co., Inc.* Los Angeles, CA: Dames & Moore.

Gates, W.E. 1992. *Confinement Barrier Integrity Review of Special Doors—Vitrification Facility—West Valley Demonstration Project.* Los Angeles, CA: Dames & Moore.

Gates, W.E. 1993. *Confinement Barriers, Design Review and Margins Assessment for Vitrification Facility.* Viewgraphs of February 23, 1993. Los Angeles, CA: Dames & Moore.

Goles, R.W. 1990. *Off-Gas System Hazard Assessment for SCR-Produced* NH_4NO_3. Richland, WA: Battelle-Pacific Northwest Laboratory.

Gupta, I.N., and K.L. McLaughlin. 1987. Attenuation of ground motion in the eastern United States. *Bulletin of the Seismological Society of America* 77(2): 366–383.

Institute of Electrical and Electronics Engineers, Inc. 1987. *Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*. IEEE-Std 344-1987. New York, NY: Institute of Electrical and Electronics Engineers.

International Conference of Building Officials. 1961. *Uniform Building Code (UBC)*. Whittier, CA: International Conference of Building Officials.

International Conference of Building Officials. 1988. *Uniform Building Code (UBC)*. Whittier, CA: International Conference of Building Officials.

Kennedy, R.P., S.A. Short, J.R. McDonald, M.W. McCann Jr., R.C. Murray, and J.R. Hill. 1990. *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards*. UCRL-15910. Livermore, CA: Lawrence Livermore National Laboratories.

Kupp, R.W. 1989. *Safety Analysis—Post-Tornado Vitrification Cell*. Letter to C.J. Roberts. Revision to May 25, 1989, Report. FB:89:0178. Los Angeles, CA: Dames & Moore.

Mazzetti, A.L. 1994. *Transmittal of December 29, 1994, Review Comment Record for the Final Safety Analysis Report (FAAR): Vitrification Plant Hot Operations and HLWIS*. Oak Ridge, TN: Performance Development Corporation.

McDonald, J.R. 1983. *A Methodology for Tornado Hazard Probability Assessment*. NUREG/CR-3058. Washington DC: Nuclear Regulatory Commission.

McGuire, R.K. 1986. *Methods of Earthquake Ground Motion Estimation for the Eastern United States*. Project No. RP-2556-16. Palo Alto, CA: Electric Power Research Institute.

National Fire Protection Association. 1993. *NFPA 70: National Electrical Code*. Hartford, CT: National Fire Protection Association.

Newmark, N.M., and W.J. Hall. 1978. *Development of Criteria for Seismic Review of Selected Nuclear Power Plants*. NUREG/CR-0098. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1973. *RG 1.61, Damping Values for Seismic Design of Nuclear Power Plants*. Washington DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1974. *RG 1.76, Design Basis Tornado for Nuclear Power Plants*. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1976. *RG 1.102, Flood Protection for Nuclear Power Plants*. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1977a. *RG 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants*. Washington DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1977b. *RG 3.40, Design Basis Floods for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Reprocessing Plants*. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1978a. *RG 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components*. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1978b. *RG 1.117, Tornado Design Classification*. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1989. *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*. NUREG-1150. Washington, DC: U.S. Nuclear Regulatory Commission

Nuclear Regulatory Commission. 1994. Policy Issue (Notation Vote). *Proposed Revisions to 10 CFR Part 100 and 10 CFR Part 50 and New Appendix S to 10 CFR Part 50*. SECY-94-194. Washington, DC: Nuclear Regulatory Commission.

Pomerening, D.J., E. Tschoepe, and P.K. Nair. 1993. *Seismic/Tornado Analysis Review for the Vitrification Facility at West Valley*. CNWRA 93-007. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Raytheon Engineers & Constructors. 1995. *Engineering Study, Soil-Structure Interaction Analyses, Vitrification Facility and Tank Farm Area*. New York, NY: Raytheon Engineers & Constructors, Inc.

Rowland, T.J. 1995. *Letter dated March 7, 1995, to G. Comfort of the Nuclear Regulatory Commission: Minutes of February 14–16, 1995, Comment Resolution Meetings for the Safety Analysis Report (SAR) for Vitrification Operations and High-Level Waste Interim Storage*. West Valley, NY: U.S. Department of Energy.

Sobel, P. 1993. *Revised Livermore Seismic Hazard Estimates for 69 Nuclear Power Plant Sites East of the Rocky Mountains*. NUREG-1488. Washington, DC: Nuclear Regulatory Commission.

Toro, G.R., and R.K. McGuire. 1987. An investigation into earthquake ground motion characteristics in eastern North America. *Bulletin of the Seismological Society of America* 77(3): 468–489.

U.S. Department of Energy. 1981. *Environmental Protection, Safety, and Health Protection Standards*. DOE Order 5480.1A. Washington, DC: U.S. Department of Energy.

U.S. Department of Energy. 1983. *General Design Criteria*. DOE Order 6430.1. Washington, DC: U.S. Department of Energy.

U.S. Department of Energy. 1989. *General Design Criteria*. DOE Order 6430.1A. Washington, DC: U.S. Department of Energy.

U.S. Department of Energy. 1990. *Conduct of Operations Requirements for DOE Facilities*. DOE Order 5480.19. Washington, DC: U.S. Department of Energy.

U.S. Department of Energy. 1992a. *Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites*. DOE-STD-1024-92. Washington, DC: U.S. Department of Energy.

U.S. Department of Energy. 1992b. *Quality Assurance Requirements and Description. Rev. 0.* DOE/RW-0333P. Washington, DC: U.S. Department of Energy: Operational Safety Division.

U.S. Department of Energy. 1994. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities—Draft*. DOE-STD-1020-XX. Washington, DC: U.S. Department of Energy.

Vance, R.F. 1989. *Estimate of Radioactivity at SCR Catalyst Bed.* West Valley, NY: West Valley Nuclear Services Company, Inc.

West Valley Nuclear Services Company, Inc. 1993. *Safety Analysis Report for Project Overview and General Information.* WVNS-SAR-001, Rev. 1. West Valley, NY: West Valley Nuclear Services Company, Inc.

West Valley Nuclear Services Company, Inc. 1994a. *Safety Analysis Report for Vitrification System Operations and High-Level Waste Interim Storage*. WVNS-SAR-003, Rev. 2, Draft D. West Valley, NY: West Valley Nuclear Services Company, Inc.

West Valley Nuclear Services Company, Inc. 1994b. *Safety Analysis Report for Low-Level Waste Processing and Support Activities*. WVNS-SAR-002, Rev. 3, Draft G. West Valley, NY: West Valley Nuclear Services Company, Inc.

West Valley Nuclear Services Company, Inc. 1994c. *WVNS Fire Hazard Analysis for the 01-14 Building*. West Valley, NY: West Valley Nuclear Services Company, Inc.

West Valley Nuclear Services Company, Inc. 1994d. *WVDP Quality List*. WVDP-204. West Valley, NY: West Valley Nuclear Services Company, Inc.

Westinghouse Risk Assessment Services. 1994. *WVNS Fire Hazards Analysis Vitrification Facility*. Pittsburgh, PA: Westinghouse Risk Assessment Services: 99.